USE WEAR AND STARCH GRAIN ANALYSIS: AN INTEGRATED APPROACH TO UNDERSTANDING THE TRANSITION FROM HUNTING GATHERING TO FOOD PRODUCTION AT BAGOR, RAJASTHAN, INDIA

Volume I

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Anthropology

2006

ABSTRACT

USE WEAR AND STARCH GRAIN ANALYSIS: AN INTEGRATED APPROACH TO UNDERSTANDING THE TRANSITION FROM HUNTING GATHERING TO FOOD PRODUCTION AT BAGOR, RAJASTHAN, INDIA

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The transition from hunting and gathering to food production is one of the most significant transitions in the cultural evolution of our ancestors. Understanding this transition is a problem of major significance in India as it lies at the historical roots of the processes by which modern agriculture and village life came about in the subcontinent. Most scholars working in India believe that the domestication of plants and animals spread to major parts of Western India from the sites like Mehrgarh located near Bolan Pass in the Baluchistan region of Pakistan.

Recent investigation of the Mewar region of Rajasthan provides a different perspective. Here, at the Mesolithic site of Bagor archaeologists have recently excavated cultural deposits that contain evidence of this important change. During this period, a culture based on hunting-gathering (*Aceramic* 5700 – 4500 B. C.) underwent a gradual and continuous evolution and developed into a food-producing economy (*Ceramic* 4500 – 3500 B. C).

The significant goals of this research was to gain a deeper understanding of the different kinds of economic and subsistence activities conducted at the site during the hunter-gatherer occupation vis-à-vis the farmers that followed. To understand the

transition at Bagor, this research used analytical techniques such as use wear analysis using reflected light Scanning Electron Microscope (SEM) along with Energy Dispersive Analysis (EDS), and starch grain analysis. Use-wear analysis was employed to get an overall understanding of the activities at Bagor by comparing microlithic tool use and changes in tool use between the hunter-gatherers and food-producers. Although use-wear analysis helps determine whether plant material was being processed, it cannot give information about the specific kinds of plants being exploited by the hunter-gatherers and food-producers at the site. To determine the kinds of plants that were being exploited by the prehistoric settlers at the site starch-grain analysis was employed.

The dissertation research shows that the last hunters became the first farmers at Bagor. This is the first time that use-wear analysis and starch-grain studies have been combined in archaeological research in India. The use-wear analysis has provided evidence of continuity and change in the different activities carried out by the hunter-gatherers and farmers at the site. The starch grain analysis recovered evidence of a range of edible plants from both soil samples and edges of stone tools. One of the significant starch grain findings was the first record of the use of egg plant. The data from use-wear and starch-grain analysis suggests that Bagor was one of the early-food producing sites in India and use of the term Mesolithic is not appropriate for the site. The study shows that analytical technique of artifact study in the lab can help in discoveries that have broader implications for the definitions of the prehistoric cultural terminologies.

This thesis is dedicated to my parents
and
to Subh for everything

ACKNOWLEDGEMENTS

This work would not have been possible without the generous support and assistance I received from my professors, colleagues, friends and family members. I consider myself extremely fortunate to have the opportunity to work under the supervision of my thesis advisor, Professor Lawrence H. Robbins. All through these years, he has been an outstanding teacher, showing extraordinary patience and support. Not only has he helped me countless time professionally; there have been several occasions when he helped me personally. For that I am indebted to him and consider him my very good friend and mentor. I am also indebted to my committee members Professor William Lovis, Professor Helen Pollard, Professor Joseph Chartkoff, Dr. Dolores Piperno and Vasant Shinde for their continuous support, help and advice. I also want to thank Professor Vincent Lombardi for being a mentor and a very good friend to me all these years. Thanks you so much for editing the dissertation. Also a special thanks to Dr. Lynne Goldstein for supporting me and providing me with funds for presenting papers at several conferences and also taking time out from her busy schedule to advice me on several occasions.

Special thanks should go to Professor Richard Yerkes, who taught me the technical details of use-wear analysis, and from whose insight I have gained immensely, and also for reading my Chapters "Technique and Methodology" and "Activities at Bagor: Results of the Use Wear Studies". Thanks goes to Dr. Linda Perry who taught me how to do Starch Grain Analysis. Thanks should also go to my friends in Anthropology through the years –Kari, Ma an, and Sarah and my friend Parama in English Department,

for their day-to-day assistance and fun-filled discussion and encouragement. I am grateful to Dr. Eva Danielewicz and Dr. Stanley Flegler for their help with scanning electron microscope. I also thank Ms. Nancy Trumble, Gail Barricklow and Peggy Meddler for their tremendous help and assistance on many different occasions. I would not be able to finish everything in time without Nancy's continuous support and help.

I also thank Professor Vasant Shinde for all his advice and giving me access to Bagor materials and soil samples. I must thank the Professors, library staff and my friends at Deccan College for their help and support also.

Last but not the least, I am thankful to my parents, my sister for their support and encouragement in pursuing a career in anthropology. My special gratitude goes to my husband Subhasish Chakraborty. He has not only made countless sacrifices for my career, but has inspired and motivated me through these years. I would not be able to complete my research without his help and continuous support. He has not only encouraged me to do better but also read and critically evaluated my grant proposals, papers and articles I have submitted to different agencies and journals. I would not be here without him.

This work was supported by the American Institute of Indian Studies, Junior Fellowship, National Museum of Natural History Smithsonian Institute, Pre-Doctoral Fellowship and Michigan State University Graduate Student Research Enhancement Award and Dissertation Completion Award.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO SYMBOLS OR ABBREVIATIONS

Symbols Used

↕ Evidence of Cutting

↓ Evidence of Impact

↷ Evidence of Piercing/Drilling

← Evidence of Scraping

Abbreviations Used

DH – Dry Hide
H – Hide
ID – Impact Damage
NT – No Trace
P – Plant
RT – Root and Tubers
SI – Cereal
SP – Soft Plant
W – Wood

CHAPTER 1

INTRODUCTION

Background

During virtually 99% of 4,000,000 years of human history, our ancestors were hunter-gatherers, dependent for their subsistence on the availability of wild plants and animals. Beginning around 10,000 years ago, one of the most remarkable revolutions in prehistory took place: during the course of the next 5000 years -- hunters became farmers in different parts of the world such as East Asia, Southwest Asia, Mesoamerica, South America, etc. (Cowan and Watson 1992; MacNeish 1992; Price and Gerbauer 1995; Smith 1995; Harris 1996; Piperno and Pearsall 1998; Denham *et al.* 2003; Neumann 2003; Kennett and Winterhalder 2006). This undoubtedly constituted one of the most significant transitions in the cultural evolution of our species. The prehistoric transition from hunting-gathering to agriculture/ from Mesolithic to Neolithic is, therefore, a topic of major archaeological interest and one of archaeology's greatest challenges. Far more than domestication of plants and animals was involved in the transition. It entailed major changes in the structure and organization of human life to include, among other things, the extensive clearing of forests, the cultivation of food that can be stored for long periods of time, the invention and adoption of new technology for farming, for herding and for storage and, above all, a transition to a sedentary village life and a more complex social and political organization (Price and Gerbauer 1995).

The prehistoric transition to agriculture poses some of the most interesting, though most difficult, questions in anthropology: Why did the hunters became farmers? How did the hunters become farmers? Where did it begin? When did it begin? These questions have been the focus of a long and fervent debate amongst anthropologists. The answer to these questions does more than enhance our understanding of prehistoric life, for their implications reverberate down to the present day; and are significant in grasping the nature of the transition to agriculture as well. The number of proposed explanations for the transition is extensive. However within broader perspectives' this fragmentary picture can be organized into three models - climate and environmental change, population pressure and socio-economic competition model (Price and Gerbauer 1995; Smith 1994; Zvelebil 1986). The climatic change and population pressure models pertain to exogenous forces; the socio-economic competition model pertains to endogenous (cultural) forces.

The Models

Climatic Change Model

The earliest of these models proposed that climate change such as the -- drying of Central Asia motivated isolated populations to initiate agriculture. The advocates of climatic change as a major force that triggered technological change include R. Pumpelly, E. Huntington and S. Cushing (Pumpelly 1908). They envisioned post–Pleistocene desiccation as impelling human beings to domesticate plants in the oases where plant and

people had taken refuge (Pumpelly 1908: 65-66). In his books *The Most Ancient East* (1928) and *Man Makes Himself* (1936), Childe amalgamated climatic change and social and economic transformation into a coherent hypotheses. For Childe the Neolithic revolution was one of "the greatest moments – that revolution whereby man ceased to be purely parasitic and, with adoption of agriculture and stock raising, became a creator, emancipated from the whims of his environment (Childe 1936)." He saw the Neolithic revolution as taking place in major river valleys such as Nile, Euphrates, Tigris, Indus and Yellow River valley. The early post-Pleistocene human groups in association with useful wild plants (as in the above mentioned river valleys) would domesticate them under stress (progressive drought and desiccation with resulting enforced propinquity at water points) they would also domesticate various species of animals. Childe's explanation seemed plausible to working scientists at the time, but little could be said about its validity because there was no supporting archaeological evidence.

The desire to obtain such information led R. Braidwood (1952) and his associates in the 1940's and early 50's to initiate an archaeological project in northern Iraq that has influenced the agricultural origins research to the present. Employing the basic concept that the search for the origin of agriculture should be in the natural habitat of the cereals, Braidwood and his team of multi-disciplinary researchers launched a long-term archaeological investigation in Iraq. Their studies called the Jarmo project, sought to recover the primary evidence for the earliest food-producing economies in the Near East.

Located 2 kilometers apart, the archaeological sites of Karim Shahir and Jarmo provided some of the earliest insights into the transition from hunting–gathering to food producing way of life. Karim Shahir was a semi-sedentary settlement occupied around

9000 years ago by a hunting-gathering society. Study of stone tools from the site attested to the hunting and butchering of wild animals especially wild goat and sheep for food. Study of other stone artifacts provided the evidence of pounding and grinding of wild plant materials including wild wheat and barley. At the site of Jarmo (2 km from Karim Shahir), dated to around 8000 years, there is clear archeological evidence of a very different way of life. At Jarmo, Braidwood excavated evidence of a permanent farming village. The careful excavation of the site provided enormous information about the way of life of the new agriculturalists: what their houses were like, how big their settlements were, how they manufactured and used their tools and how and where they cooked their food, etc.

The geo-morphological and paleoclimatological evidence at the sites, however, provided no support for Pumpelly's (1908) and Childe's (1936) suggestions about the desiccation of the early Holocene Near-East. The studies showed no indication of major climatic differences between the early food production era and the present. Childe's and Pumpelly's arguments for the transition were centered on the human need for plant food and lacked any consideration of cultural features. Braidwood utilized cultural rather than environmental factors in formulating an alternative to Childe's suppositions. He argues that, with the expansion of human technology and human knowledge about the physical environment, humans gradually realized the potential inherent in the local flora and fauna and exploited that potential by domesticating the appropriate species.

Unfortunately, the overly deterministic nature of the environmental change theory provoked a backlash in the broader archaeological community against the importance of the changing environmental conditions during the late Pleistocene and Early Holocene.

For many years the role of climate change was simply ignored relative to other mechanisms perceived to have greater explanatory value that continues even today (however there are several noteworthy exceptions to this -- Piperno and Pearsall 1998; Kennett and Winterhalder 2006: 8), despite the development of sophisticated palaeoenvironmental techniques (Piperno 1988) and advances in high-resolution climate records (Rittenour *et al.* 2000).

The climatic records show that the domestication of key cultigens in the Old and New worlds occurred during an interval marked by significant fluctuations in the global climate. These changes brought with them regional biotic shifts on resource abundance and density (Kennett and Winterhalder 2006: 9). Some regions witnessed the extinction of several large animals, a product of environmental change and intensified human exploitation at the end of the Pleistocene period. Others experienced the expansion of wild plant species that were intensively harvested by the forager and, slowly through selective manipulation, became important cultigens (Kennett and Winterhalder 2006: 9). These changing environmental conditions led many foragers to alter their subsistence resulting in dietary choices that spurred on plant and animal domestication – significant transition that culminated in an agricultural revolution.

Population Pressure Model

Moving beyond the climatic change model, Mark Cohen (1977) (influenced by earlier writers, especially Ester Boserup 1965) proposed population pressure as the key to the transition from hunting–gathering to agriculture stage. The beginnings of agriculture some ten thousand years ago approximately coincided, Cohen pointed out, with the end

of the long process of human expansion throughout the habitable portions of the planet. As population continued to grow with nowhere new to go, global density would have begun to increase rapidly; wild plant and animal food sources gradually were ever less sufficient for human survival. Our ancestors took up farming only when, and to the extent that, they had to, Cohen (1977) concluded.

Scholars such as Binford (1968) and Flannery (1969) propose the "marginality" or "edge" hypothesis. Drawing from ethnographic and demographic studies such models propose that groups living in the optimal zones would maintain a population below carrying capacity. They postulated that human groups colonizing the optimal zones such as the hilly flanks would maintain a dynamic equilibrium between population size and natural resources below the regional capacity. However, this balance can be disturbed by a change in the environment, which can result either in a population increase on the global or regional scale or a decline in available resources. Both these factors can cause groups to impinge on the territory of others', putting pressure on each other's resources. This would lead some of these groups to intensify their subsistence practices in the direction of domestication of plants and animals.

One of the responses to the early overemphasis on demography has been to heavily discount its importance in the process of domestication and agricultural development (Hayden 1990; Hayden 1995). Studies on hunter-gatherers have shown that they clearly have dynamic relationships with their resources and this, in turn, has population effects (Winterdaler and Goland 1993; Winterhalder *et. al.* 1988). Even small hunter-gatherer populations alter the distribution and availability of harvested plant and animal species (Stiner *et al.* 1999). However, independent of humans, environment

change is ubiquitous and also affects the distribution and availability of important species. The economic decisions made by the prehistoric foragers to experiment with and, later, domesticate some plants and animals occurred within this dynamic context of demographic change and varying plant and animal densities (Kennett and Winterhalder 2006).

Socio-economic Competition Model

Despite the increasing attention given to the external factors (or exogenous factors like climate change and population pressure), some archaeologists have continued to focus on the endogenous or internal changes within the society to explain this transition. Scholars such as Bender, (Bender 1978; also see Hayden 1995: 289) stress the importance of social competition. They insist that social competition is part and parcel of human nature and that this social competition within and between the hunter and gatherer populations led to status and wealth accumulation. Thus farming was adopted as a more intensive means of production than hunting and gathering to maintain social control or as a consequence of competition in maintaining status and power. The mechanism for change in these models is status-seeking individuals who usually encourage and control the growth of potential domesticates in order to create a surplus for social purposes such as competitive feasting, alliance formation, etc. Surely the social significance of food is obvious. Yet there are several fundamental flaws with this model. As a stand-alone model for explaining agricultural origins, the model fails on two accounts. First, it lacks a unifying explanation of why agriculture developed in several independent regions of the world at around the same time (Piperno and Pearsall 1998: 14; Kennett and Winterhalder

2006: 10). Second, although there is evidence that agriculture often developed in resource rich regions of the world (Price and Gerbauer 1995) the initial domestication of most of the plants and animals in the world occurs well before the conditions promoted socio-economic competition, at least in Asia, Africa and Americas (Piperno and Pearsall 1998; Kennett and Winterhalder 2006).

New Perspectives

Although the three models proposed above are interesting, archaeologists have realized that, by themselves, they are very simplistic given the evident variation present in different environmental contexts. The transition from hunting and gathering to food production not only happened at different times in different places, but the process was also in many cases remarkably different. Since the 1970's a substantial amount of new information has been collected as a result of a large number of excavations in different parts of the world. Moreover there has been an introduction of a wide range of new field and laboratory techniques and experimental studies that allow us to study the questions posed about the transition to food production with much more confidence. A number of important works present various aspects of this growing body of new information and show that answers to some of the questions about the transition are not as straightforward as they seem (Harris and Hillman 1986; Harris 1996; MacNeish 1992; Price and Gerbauer 1995; Zvelebil 1995, 1996; Piperno and Pearsall 1998; Denham *et al.* 2003; Kennett and Winterhalder 2006; Kislev *et al.* 2006; Weiss *et al.* 2006). Traditionally, it was thought, for example, that hunting and gathering constituted a simple mode of

subsistence, capable of supporting only small groups that had to be constantly on the move to eke out a living. Thus, it was concluded that hunter-gatherers offered little competition to farming or livestock domestication as an economic mode. Therefore it was thought that agriculture, as a highly productive economy, spread rapidly from the Near East to the different regions, through colonizing farmers or adopted by the foraging bands quick to see its potential for improving their poor living.

With new world wide studies, it has become clearer that in favorable environments such as those in Northern Europe, hunting and gathering were capable of supporting populations much denser than recently thought (Bogucki and Grygiel 1983; Zvelebil 1986). Current interpretations within various parts of Europe (such as Pitted Ware Culture site of Southern Sweden, the Deer Island Cemetery site in Northern Russia and others) suggest that some foragers may have lived relatively sedentary lives in permanent settlements where elements of social differentiation were present. Such communities did not readily adopt farming and in Northern Europe it was a long delayed process, 'more like a series of dashes, punctuated by long periods of waiting' (Zvelebil 1986). Anthropologists now agree on the independent origins of agriculture in different areas during the early Holocene. There is also a consensus on some of the most important variables involved in the shift from the foraging to farming such as proto-domesticates, human sedentism, higher population density, geographical or climatic constrains, processing and harvesting technology and storage and wealth accumulation.

Transition in South Asia

Despite great strides in the knowledge of how, when and why the transition from hunting-gathering to food production happened in different parts of the world (e.g., Southwest Asia, Mesoamerica and Europe etc.), these questions have been somewhat neglected in South Asia. Known as the Indian subcontinent, South Asia comprises the major modern states of Bangladesh, India, Nepal, Pakistan and Sri Lanka) and has largely been ignored in the discussions on the transition to food production by world wide scholars (Meadow 1996). This dearth of recognition is largely due to the low visibility and uneven quality of the archaeological research carried on in this region (Fuller 2002, 2004; Meadow 1996). Published by a few practioners, primarily in the local journals and in South Asian produced books, it has not attracted the attention of world archaeologists. As a result it is becoming very clear that more research needs to be done before something can be securely said about these processes in South Asia. It is now evident from the little we know that the development and spread of agriculture and pastoralism in South Asia is a complex phenomenon taking place over the course of more than nine millennia (Allchin and Allchin 1982; Fuller 2002; Korrisettar *et al.* 2002; Liversage 1983; Meadow 1996, Singh 2002) in several different areas of the region (Figure 1.1 and 1.2).

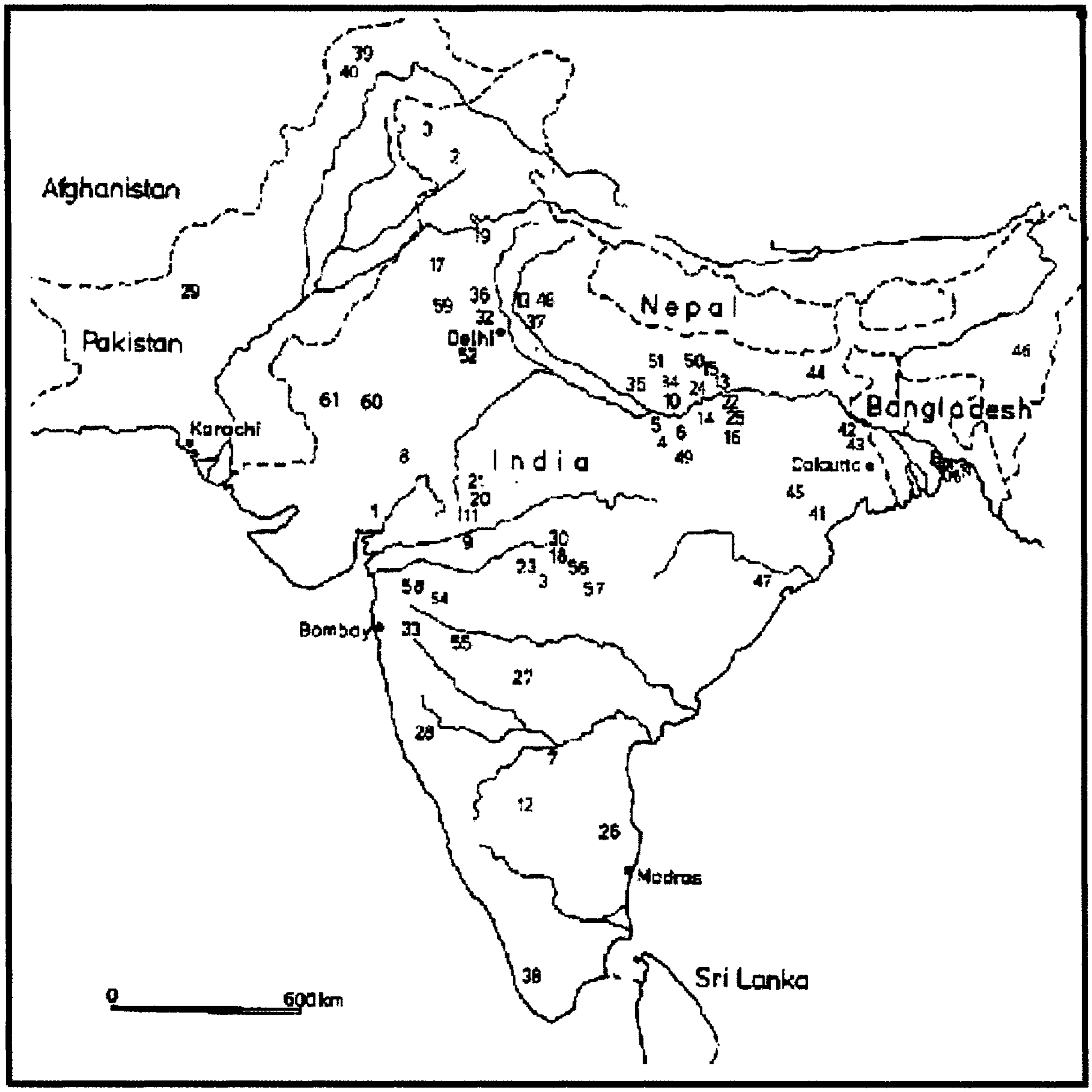

Figure 1.1: Distribution of Prehistoric and Protohistoric Archaeological sites in India (After Glover and Higham 1996, Figure 23.8, pp. 418) Sites include – 1. Lothal, 2. Gufkral, 3. Semthan, 4.Koldihwa, 5. Mahagara, 6. Chopani Mando, 7. Veerapuram, 8. Ahar, 9. Navdatoli, 10. Dangwada, 11. Hallur, 13. Hastinapur, 14. Sonepur, 15. Chirand, 16. Taradih, 17. Baidaypur, 18. Nevasa, 19. Rupar, 20. Ujjain, 21. Nagda, 22. Pataliputra, 23. Kaundinyapur, 24. Rajghat, 25. Rajgir, 26. Kunnatur, 27. Ter, 28. Kolhapur, 29. Pirak, 30. Bhagi- Mohari, 31. Khairwada, 32. Lal Qila, 33. Walaki, 34. Narham, 35. Sringvepur, 36. Daulatpur, 37. Hulas, 38. Adichanallur, 39. Aligrama, 40. Loebanr III, 41 Biadapur, 42. Mahisdal, 43. Pandu Rajar Dhibi, 44. Oriyup, 45. Barudih, 46. Ambri, 47. Puri, 48. Atranjikhera, 49. Barunha, 50. Mahga, 51. Sohgaura, 52. Noh, 53. Kakolia, 55. Inamgaon, 56. Naikund, 57. Paunar, 58. Bhokardan, 59. Kohkrakot, 60. Bagor, 61. Tilwara

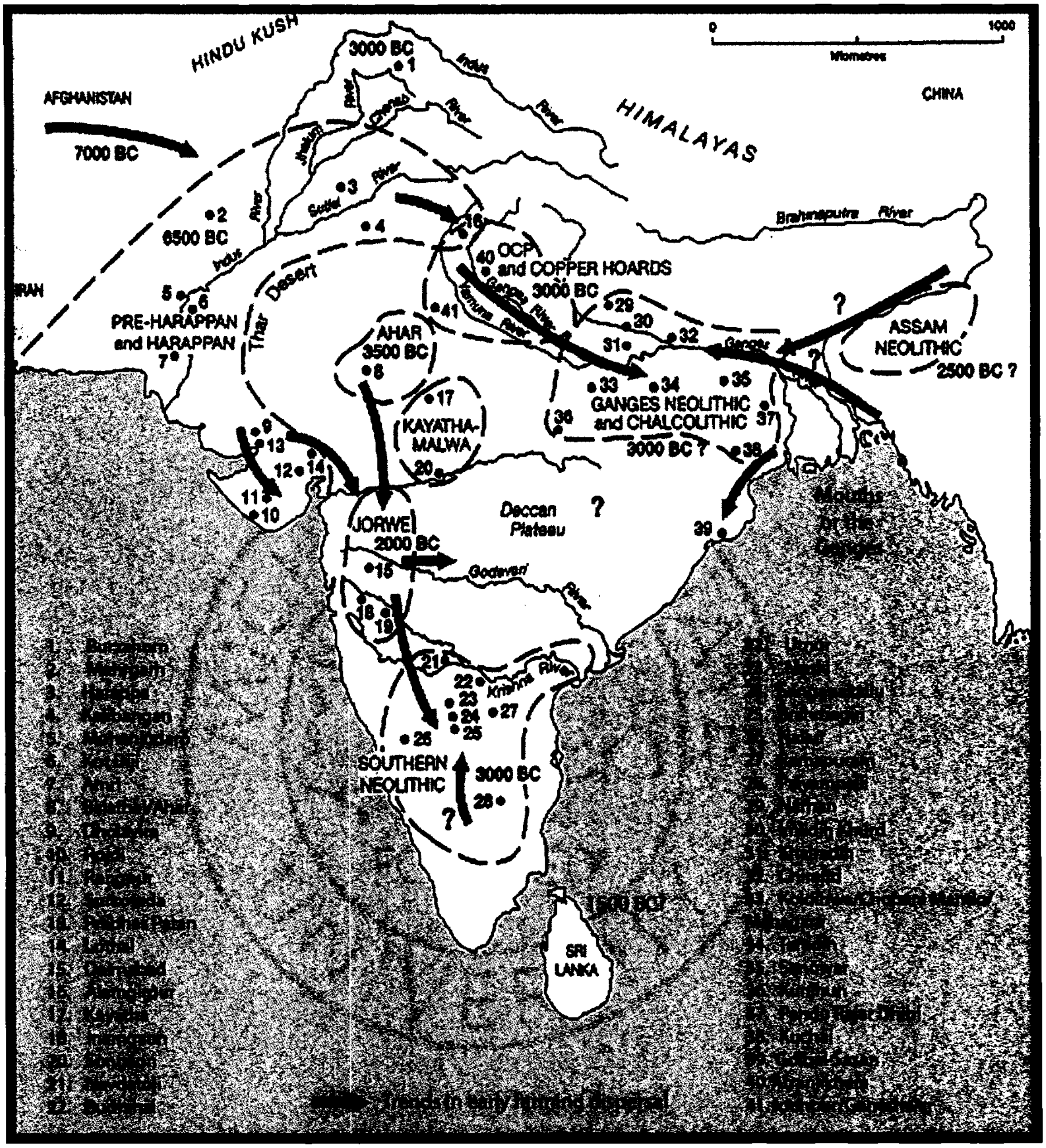

Figure 1.2: The Early Farming Cultures of South Asia (After Bellwood 2005, Figure 4.7, pp: 89)

Liverage (1989) proposed a simple classification of four Neolithic regions in South Asia which he proposed had distinct, prehistoric, agricultural traditions based on different, but overlapping, kinds of crops. These include Baluchistan, the Indus Valley, and a large, west-central Indian region extending from the Aravallis to the Deccan. For Liverage these 'complexes' were unified by similar ecological conditions and presumed cultural interaction; a broadly similar division was also discussed by Allchin and Allchin (1968) and Hutchinson (1976). This division has been modified since then. Most scholars now agree on three centers–the North-West or the Indus system, Vindhayan region (including the Ganga - Belan valley), and Southern India.

Northwestern or the Indus System

The earliest evidence of the transformation from the hunter-forager to farming economy in this region of South Asia comes from the sites of Mehrgarh and Kile Gul Muhammad in Baluchistan (See Figure 1.3). Here winter crops such as barley and wheat dominate the agricultural economy of the Aceramic period I (Constantini 1984). The earliest evidence (radio-carbon dates ranging from less than 4000 B.C. to more than 8000 B.C.) comes in the form of impressions of seeds in mud bricks together with some charred remains (Jarrige 1985). Dominating the assemblage of the Mehrgarh Period I are *rabi* or winter crops such as the naked six row barley (*Hordeum vulgare*), wild and domesticated hulled two-row barley (*H. vulgare* subsp. Spontaneum and *H. vulgare* subsp. Distichum respectively) the latter present in much smaller amounts. Also found are remains of domestic einkorn (Triticum monococcum) and domestic emmer (T. turgidum subsp. dicocum). Towards the end of the Aceramic phase – by about 6000 B.C.

– sheep, goat and cattle were reared as domesticated animals and cattle breeding replaced hunting as the dominant form of animal exploitation. At this stage naked barley was being cultivated and rows of large, compartmented storage buildings were built in well-defined areas. The settlement now grew in size, but the socio-economic pattern remained unchanged in the course of sixth and fifth millennium B.C.

By the end of the fifth millennium, there was a marked change in the settlement pattern of the site. By this time six medium-sized settlements sprang up in these areas. At Mehrgarh itself, the settlement shifted to the south where clusters of houses with private courtyards, domestic installations and storage jars have been exposed. This change in the settlement pattern coincides with one in agriculture. Cultivation of wheat – a *rabi* crop that previously had been very limited – becomes important thus attesting and is evidence of a greater diversification of the economic base.

Although there is a possibility that local wild barleys could have been brought under cultivation independently in the Mehrgarh area, this is much less likely for wheat (Meadow 1996). So how did this transition happen? And, how did wheat become an important domesticate here?

Mehrgarh is situated where the Bolan River comes out of the Brahui hills and enters the North Kachi plains. The North Kachi plain is a semi-arid region where the wild ancestors of wild barley grow. It has been postulated that during the Late Pleistocene, hunter-gatherers fed themselves by collecting wild grasses and wild barley and fruits in the foothills and by hunting animals on the open slopes and on the plain near watering points. By the early seventh millennium B.C., (Jarrige 1985: 38), however, increase in population must have led to cereal cultivation in the flooded fields of grasses

to include barley (the wild species of which has been identified in the region) and diversification of crops by adoption like wheat from Southwest Asia (Meadow 1996).

In his discussion on how the transition to agriculture happened in the Northwest part of the Indian subcontinent, MacNeish (1992, pp. 261-263) points out that this region was a non-center of secondary development Here the blade and burin, Upper-Paleolithic remains represent Hunting–Collecting Bands (systems A) and the microlithic cultures represent Affluent Foraging Bands (system C). These in turn became the Foraging villagers (System C1), who evolved into Aceramic Neolithic Horticultural Villagers (System C2) and thence the Neolithic Agricultural Villages (System E) with most of the plants being imported. A case is made to establish that this region had the necessary condition for secondary development. "Its oasis and Indus valley location are lush and have various ecological zones that can be exploited from a strategically located base. They seem circumscribed by deserts, and the region is next to a Center – the Near East - with which it obviously interacted (MacNeish, 1992: 263)."

Meadow (1996, 1998) also talks about such an interaction "Our understanding of agriculture and pastoralism in northwest south Asia has advanced somewhat since 1975 … We now accept that neither mountains nor seas were ever barriers to communication or the movement of people, materials. Interactions with the regions to the Northwest, West and Southwest were continuous although of varying intensity and provided the means of introduction of new plants, people and animals (Meadow 1996: 406 - 407)". Today a hilly road follows the course of the river Bolan into the Iranian plateau. This is probably an ancient route between the plateau and Indus valley and perhaps one of the paths used by pastoralists/traders moving back and forth between the

Figure 1.3 Neolithic Sites in Northwest or the Indus Valley System *(After Meadow 1996*, Figure 22.1, 394*)*

regions, exchanging food coming from domesticated plants like wheat and barley, ideas and materials.

The prehistory of other crops (such as rice, pulses like Vigna sp., and Macrotyloma sp., sesame and rice) that was a part of the ancient South Asian agricultural economy (both rabi and kharif/summer crops) is more complex and even more poorly known than that of wheat and barley. This discussion brings us to the next region the Central Ganga Valley and the Vindhyan region.

Central Ganga Valley and the Vindhyan region

The Ganges basin, with major tributaries such as Yamuna and Belan, etc. witnessed a cultural trajectory from the Neolithic period onwards which was different in style and detail (Bellwood 2005). Four key sites here are Koldihwa, Mahagara and Chopani Mando and Sarai-Nahar-Rai.

An argument has been put forward for the domestication of rice in this region[1] (Sharma *et al.* 1980). Sharma *et al.* have proposed, the earliest evidence of rice in India from the "proto-Neolithic" levels at Chopani Mando in the Ganges valley, which had been dated to 8–7th millennia B.C. (Sharma *et al.* 1980, Vishnu-Mittre 1989). "It is no longer possible to hold that India was a part of the South Asiatic non-center of agricultural origin." They argue that until more coherent and conclusive evidence of greater antiquity is available from other regions, this area of India – the Belan valley in

[1]Recent excavations at the site of Lahuradeva in Uttar Pradesh have revealed the remains of carbonized material containing grains of cultivated rice along with wild grass dating back about 10,000 years. If this is true, then Middle Ganga Valley could be the home of the first farmers in the world.

the Vindhyas – will remain an original primary and nuclear center for the beginning of rice cultivation and the domestication of animals." In this region the sites of Koldihwa, Chopani Mando and Mahagara (Figure 1.1 and 1.2) provide an uninterrupted story of a continuous sequence of transition from the stage of intensified food gathering and selective hunting (Epi-Paleolithic) through incipient food-producing (Advanced Mesolithic or Proto-Neolithic) to settled village farming. Coarse, cord-impressed pottery contained many impressions of rice stalks, glumes and spikelets, as well as charred grains that have been identified as domesticated rice (Sharma *et al* 1980). Continuity is also seen in the tool types and in the huts and domestication of animals. New types of tools – ground stone axes, both round and square were added during the different phases to the principal tool types, which include parallel-sided blades, blunted back blades, points, burins, scraper and lunates. This picture of continuity and innovation are also evident in the querns and mullers. The concavities in Neolithic querns were produced by pounding on domesticated plants in the Mesolithic ones the concavities are shallower and are produced incidentally by pounding and grinding of hard grains, wild grasses and cereals.

In discussing about this region of South Asia, MacNeish (1992, pp. 263-264) refers to the site of Sarai-Nahar-Rai in the Ganges valley. "This site dated to 8300 B.C. was a large village of beehive structures . . . Tools and faunal remains of wild and domesticated animals indicate that people were probably sedentary foragers. If so, they were Foraging Villagers or System C1–but the archaeological evidence suggests that they may also have had domesticates and practiced horticulture. At present it seems both foraging bands and village systems existed side by side in Central India during the

Mesolithic. But exactly when village Horticulture (System C2) or agriculture began in this region is difficult to determine. The Neolithic village of Koldihwa on the Belan River . . . had impressions of possible domesticated and wild rice on some pottery dated to 6560–4500 B.C. (MacNeish 1992, pp. 264)." However when the ecological factors are taken in consideration, MacNeish suggests only a tertiary development for the site locations in the Ganges valley. The valley is lush with food resources abundant during all seasons. According to MacNeish Mesolithic people may have has little need for agriculture, but he admits that much more solid research before we can clarify the situation.

More recent reviews have also been skeptical of the claims of the excavators. According to Glover and Higham (1996) ". . . these sites are most unlikely to be older than mid-late third millennium B.C., even so they provide some of the earliest evidence of domesticated Asian rice within an agricultural system in South Asia (1996, pp. 416). More research needs to be done before something sustentative can be said about the domestication of rice in this region of India." Fuller (2002) points out that "unfortunately the plant remains were not collected systematically by flotation." There is no clear temporal evidence suggesting a move from wild to domestic type rice at the site. The Koldihwa material was offered as evidence as both wild (*O. rufipogon* and *O. nivara*) and domestic (*O. sativa*) kinds of rice occurring together (in the reports the evidence of wild rice actually post dates that of the domesticated rice). Also co-occurrence by itself cannot be used to suggest domestication since wild species of rice often occur as weeds of rice fields (Fuller 2002, Kumar 1988, Vaughan 1989). Thus the impressions of wild and domesticated rice in potteries from Koldihwa and Mahagara

appear to indicate that the crop-processing waste of rice was used as temper. This unfortunately says nothing about the domestication of rice at these sites.

Plausible botanical arguments for an independent domestication of rice in India can be made, now with recent discoveries. Researchers have found a wide distribution and diversity of wild rice in India, which has prompted suggestion that the *indica* culitvars may have originated in India and spread from there to South-East Asia and China (Kumar 1988; Shastri and Sharma 1974; Vavilov 1992). Recent studies on the DNA sequence variation of *Oryza rufipogon* (wild ancestor of rice), and excavations at Lahurdeva[1], however, indicate that India and Indochina both, may represent the ancestral center of diversity for *O. rufipogon* (Londo *et al.* 2006).

South India

In south India (including peninsular India, Figure 1.4) the Neolithic culture subsisted on large herds of cattle. The predominant sites are ash mounds. The southern Neolithic offers a distinctive picture, considerably later than Indus valley or the Ganges region (Korisettar *et al.* 2002). The earliest Neolithic sites were based on cattle pastoralism, and date back to about 2800 B.C. (Bellwood 2005). A classic site in this series is the Utnur ash mound, which had a sub-rectangular stockaded enclosure fenced with palm trunks. The enclosure is around 60 meters long and sufficient for 500 cattle. Inside the stockade was found a thick layer of burned cow dung, with several hoof impressions. Dwelling huts were constructed between the enclosure and a separate outer stockade (Bellwood 2005: 92; Allchin 1968; Allchin and Allchin 1982: 123).

Another important ash mound site is Budhihal, dated to 2300 B.C. The site had four cattle pens. Of these the major excavated examples, Budhihal Locality 1, contained a 3-meter high mound of burned dung, an adjacent animal pen fenced by a rubble embankment and a flanking habitation area of about 1.3 hectares with stone foundations of rectangular and oval houses (Bellwood, 2005: 92-93). The derivation of the dung is attributed to periodic burning to reduce the number of flies. Such periodic burning suggests that the dung was not in demand as a fertilizer and that field agriculture, therefore, might have been absent. However analysis of plant remains from Budhihal (Paddayya 1993 a and b, 1998; Kajale 1996) have revealed some barley, horse gram, bean and millet type seeds; so we cannot assume that these people were purely pastoralists.

The second major types of settlements, that developed around 2000 B.C. and onward is located on the granite hills of the region. On these terraces round huts made of wattle and daub and supported by wooden posts were built on each terrace. One or two huts were built on each terrace, and the settlement, in some cases, extended from the hill to the plains. Layers of accumulated occupation debris and mud floors indicate continuity of some centuries before the villages moved down onto the plains, a process which seems to have begun with the Iron Age around 1000 B.C. The Neolithic culture subsisted on both millet and large herds of cattle.

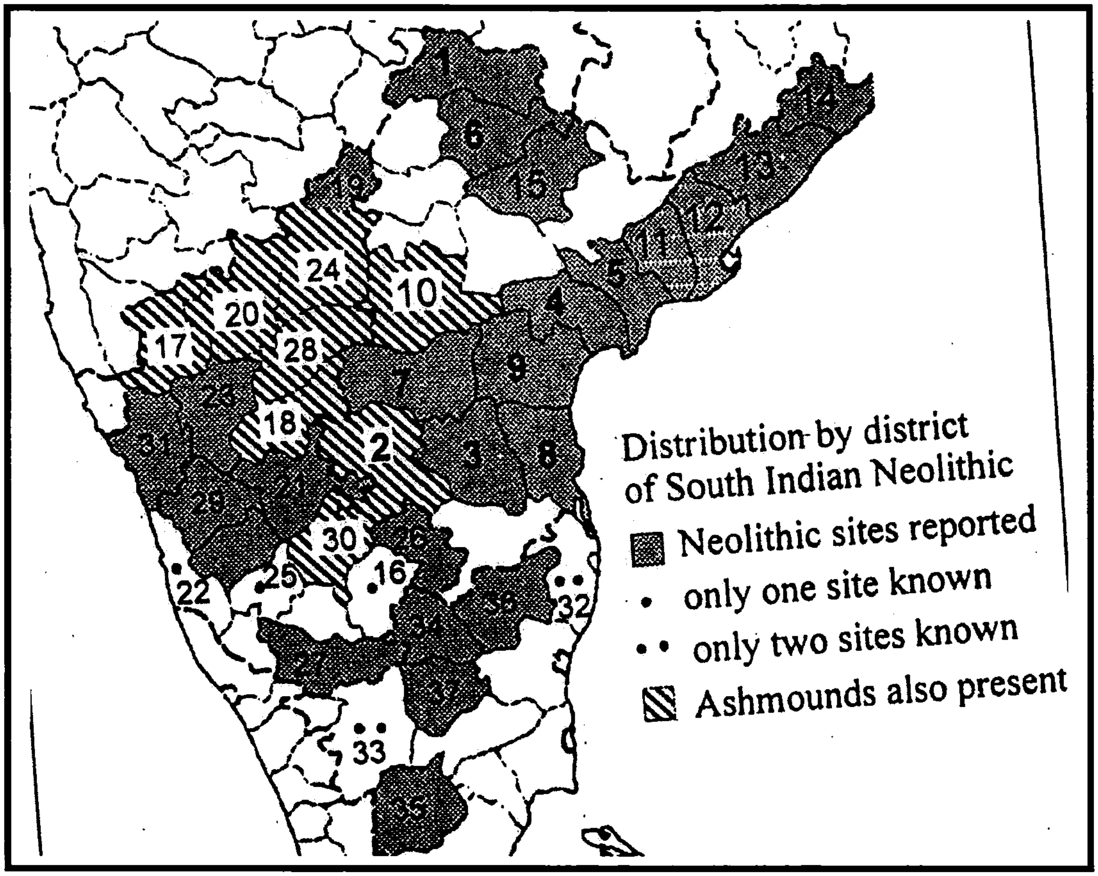

Figure 1.4: Map Showing Neolithic Sites in South India (After Korisettar *et al.* 2002, Figure 1, 152) Districts are numbered: 1. Adilabad, 2. Anantapur, 3. Cuddapah, 4. Guntur, 5. Krishna, 6. Karimnagar, 7. Kurnool, 8. Nellore, 9. Prakasham, 10. Mahbubnagar, 11. West Godvari, 12. East Godavari, 13. Vishakapatnam, 14. Srikakulam, 15. Warangal, 16. Bangalore, 17. Belgaum, 18. Bellary, 19. Bidar, 20. Bijapur, 21. Chitradurga, 22. Dakshina Kannada, 23. Dharwar, 24. Gulbarga, 25. Hassan, 26. Kola, 27. Mysore, 28. Raichur, 29. Shimoga, 30. Tumkur, 31. Uttara Kannada, 32, Chigleput, 33. Coimbatore, 34. Dharmapuri, 35. Madurai, 36. North Arcot and 37. Salem

On the basis of the available evidence it seems probable that the southern Neolithic originally developed as a predominantly pastoral economy supported by the collection of wild grains, until millets made their appearance around the end of the third millennium. This would help us to explain why the earliest settlements are ash mounds, while the hill settlements with terraced fields appear later, around 2000 B.C.

The above discussion makes it amply clear that most regions of South Asia need more research before anything solid can be said about them. One conclusion is clear however: the transition to food production happened at different time periods in different parts of South Asia and the processes involved were also very different.

New Evidence: Mewar Region of Rajasthan

Recently closer investigation of the Mewar region of Rajasthan (Figure 1.5) provided new evidence about Western India (Shinde 2002; Shinde *et al.* 2004). Most scholars believe that transition from hunting gathering to agriculture in this region was primarily due to diffusion from sites in Bolan Pass like Mehrgarh, Kile Gul Mohammad and others around three thousand years ago. However, new paleoclimatological and archaeological research have shown that the antiquity of the human settlement in the desert goes back to the Middle Pleistocene (Misra and Rajguru 1989; Shinde *et al.* 2004). Environmental studies have shown that during the Middle and Early Upper Pleistocene environmental conditions were much better than today (Misra and Rajaguru 1989).

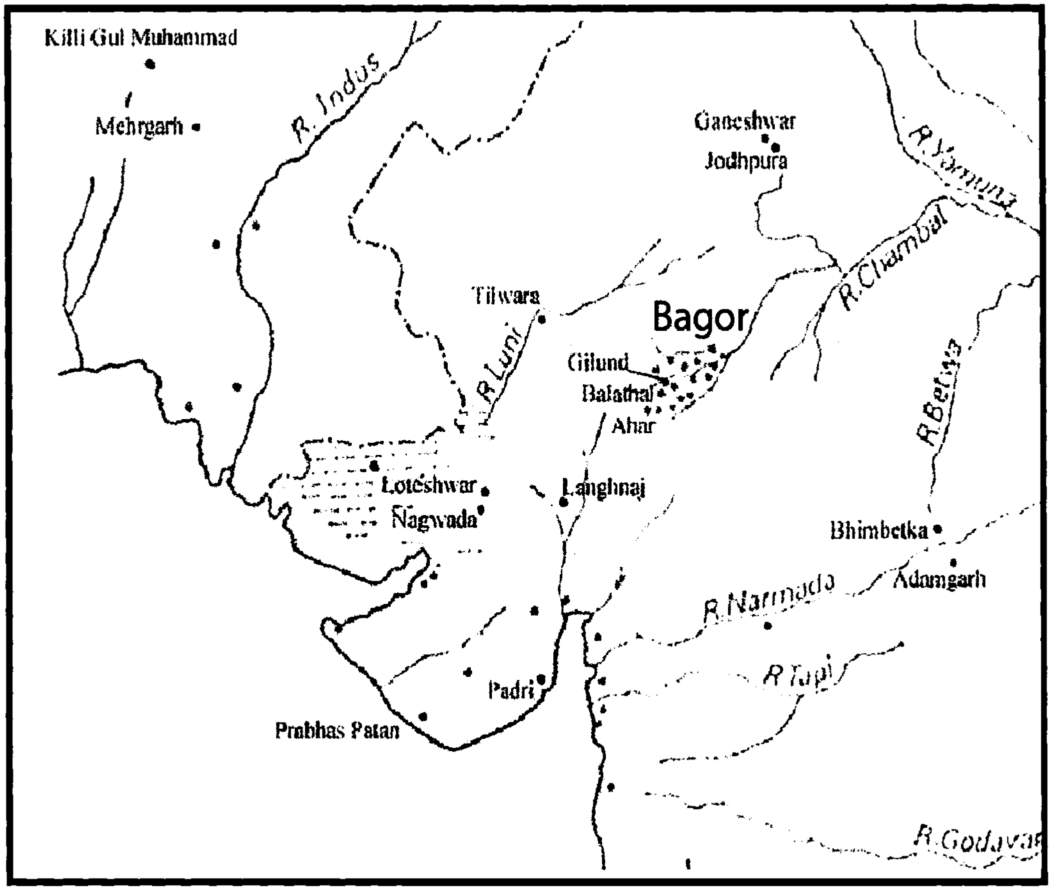

Figure 1.5: Neolithic Sites in Western Mewar Region, India (After Shinde *et al.* 2004, Figure 3, 385)

There was significant movement of human population in the region as substantiated by the extensive occurrence of Mesolithic sites during the Holocene. It has been proposed that the improved climatic conditions (around 10,000 years ago) and abundance of plants and animal food in the semi-arid region of Western India led to an explosion in Mesolithic hunter-gatherer population. The sudden increase is evident in the large numbers of Mesolithic settlements in Rajasthan, Malwa and Gujarat (Misra 1994; Misra and Rajguru 1989; Shinde *et al.* 2004). This was the result of increased rainfall and the consequent increase in the plant and animal resources in the region (Singh *et. al.* 1974). Throughout this period the economy of human groups was based on hunting and gathering. Changing environment around the middle of the Holocene, population pressure and depleting resources, however, forced these Mesolithic groups to adopt an agrarian life style and settle in congenial environments that had better resources, such as water, plant and animal life that provided opportunities for selecting cultigens and domesticating animals (Shinde *et al.* 2004).

According to Shinde (2004, pp. 389) "The earliest 'Oasis theory' propounded by Childe for the rise of domestication today seems more plausible based on the available evidence from the region of our study (*here he is referring to Western Rajasthan*). Recent studies carried out by scholars in the Middle Ease and north east Africa (Hassan 2002) suggest the rise of domestication as an answer to a spell of droughts between 7500-600 years BP and its spread is attributed to cultural interaction. A series of developments all over the world include:

- development of specialized and mixed economies
- ability to develop innovations at a relatively fast rate

- environmental changes or 'climatic kickers'
- rise of cultural nodes or centers of interaction in the climatically sensitive zones (arid or sub-arid regions) referred to as 'ekotropic regions'
- within the ekotropic regions are 'cultural troughs,' i.e. localities with regular flow of water and plants or buffer zones where animals and humans converge in the absence of other such nodes of congregation and overcome occasional food scarcities and develop in the mean time innovative strategies to cope with disasters. These regions are also characterized by high plant and animal diversity providing the opportunity for selecting cultigens"

According to Shinde (2004), these factors seem to have contributed in the region of western India to all necessary conditions to spark the beginning of a transition to agriculture and domestication. This convergence of plants, animals and humans was especially notable in south east Rajasthan, where the source of water interfaced with rich plant and animal diversity. The evidence for this series of development is best documented at the Mesolithic[2] site of Bagor, in the Mewar region, Rajasthan, India.

[2] The term Mesolithic is used to refer to Old World archaeological assemblages that fall within the Holocene (Possehl and Rissman 1992). The Mesolithic has traditionally been seen as the period of small bands of nomadic wanderers, who subsisted on hunting and foraging and lacked evidence of food production. However in Indian archaeology the Mesolithic is a much-abused concept. Confusion over the definition of the Mesolithic–settlement and subsistence versus tool typology – has muddled much of the writings in Indian archaeology (Possehl and Rissman, 1992). Some archaeologists have defined Mesolithic on the basis of subsistence and settlement patterns of the prehistoric people (e.g., Sussman *et al.* 1983). Other archaeologists (e.g., Misra 2001) imply that if a tool assemblage contains microlithic it is thereby Mesolithic by definition – basing the term Mesolithic strictly on tool typology. Although there is evidence of food production at Bagor, the site is still categorized as Mesolithic by its excavators, because prehistoric settlers here made microlithic tools- blades, crescents, triangles, points, etc.

Here archaeologists have excavated deposits of a Mesolithic period (in a well-defined archaeological context) that contain evidence of this important change. During this period, a culture based on hunting–gathering (Aceramic Mesolithic) confined to 25 cm of the habitation layer 3 (cal. years 5700–4500 B.C.) underwent a gradual and continuous evolution and developed into a food-producing economy (Ceramic Mesolithic) layer 2 (cal. years 4500–3500 B.C) (Shinde *et al.* 2004). Thus, this site provides unprecedented evidence of how the economic activities and modes of subsistence changed in the same setting. The available data better inform us about the significant variables underlying the transition. In spite of the tremendous potentials, however, this site has not been thoroughly studied. The stone tool research has been limited to typo-technological studies (Inizan and Lechevallier 1995; Misra 1971, 1973; exception Khanna 1995).

The study of plant and animal remains continues to be haphazard and the results still need to be integrated into a broader archaeological picture (Although scholars like Vasant Shinde have expressed concerns in personal communication about the need to implement new research objectives and methodologies in India). What little we know confirms an expected, intimate acquaintance with local wild animals and perhaps also plant resources. How these resources were exploited by hunter-gatherers and whether these resources were locally husbanded by farmers are questions yet to be investigated.

Present Research

To understand these changes two sets of research questions were addressed:

The first set of questions relate to the activities of the prehistoric settlers at Bagor.

A. **What were the subsistence and economic activities carried out by the hunter-gatherers at Bagor? OR, what kinds of activities were performed with the tools by the hunter gatherers?**

B. **What were the subsistence and economic activities of the farmers at Bagor? Did the utility of the tools change with the change to food production?**

The second sets of questions seek to determine the kinds of plants exploited by the prehistoric settlers at the site –

A. **What kinds of plants did the hunter-gatherers exploit?**

B. **What kinds of plants did the earliest farmers at the site use?**

To answer these questions an in depth study of cultural materials like microlithic stone tools and plant residue from the site of Bagor was carried out. Two different methods – use-wear analysis and starch-grain analysis – were used.

Along with this study a fully detailed clarification of the fauna and the botanical remains (when published) will provide significant information on the subsistence pattern at the site. When that is done it should be possible to compare these results with the revealed microscope-based data revealed data providing a distinct, multiple and correlative examination of evidence from the Bagor site.

Methods

With the developments of these new, investigative techniques – use-wear analysis of stone tools and plant residue studies such as phytoliths and starch-grain analysis (in the

absence of macro-botanical remains)–one can penetrate the economic life of prehistoric people. These important data open a new vista into human evolution by shedding light on the subsistence histories of the prehistoric sites. Indeed these new research techniques are able to answer the above questions precision and accuracy. Use-wear analysis was employed to get an overall understanding of the activities at Bagor by comparing microlithic tool use and changes in tool use between the hunter-gatherers and food-producers. Although use-wear analysis helps determine whether plant material was being processed, it cannot give specific information about the specific kinds of plants being exploited by the hunter-gatherers and food producers at the site. This requires combining and complementing plant-residue analysis with use-wear research to reconstruct the kinds of plant food processed at the site by the prehistoric settlers. Here plant-residue studies such as starch-grain analysis can help. Together use-wear and starch-grain analysis can provide a more reliable and precise reconstruction of the economic behavior of prehistoric people in the Mesolithic and Neolithic cultural stages of human evolution.

Organization of the Dissertation

Chapter 2 will present in detail the methods and techniques used for this research. In **Chapter 3** an overview is given of the Mesolithic Age in India and the archaeological site of Bagor; its Mesolithic remains are discussed in details. **Chapter 4** treats the use-wear analysis of the microliths from the various Aceramic and Ceramic levels at Bagor; an in depth analysis of the wear traces is provided. The results will show both continuity and significant change in the use of the microliths from the

Aceramic to the Ceramic phase. **Chapter 5** presents a detailed discussion of the results of starch-grain analysis of the stone tool and soil samples and helds us to determine the plants exploited by the Mesolithic settlers at Bagor. **Chapter 6** presents the conclusions of the research and future directions.

CHAPTER 2

TECHNIQUES AND METHODOLOGY

Introduction

This chapter will discuss in detail the techniques use-wear analysis and starch-grain analysis, the history of their application in archaeology, details of the methodology and the success of these new diagnostic tools in answering questions raised in Chapter 1.

Lithic Analysis: Use-wear Studies

Lithic use-wear analysis is an experimental and replicative technique for the microscopic examination of the wears that form on the edges of stone tools used for different tasks. Researchers have shown that different fractures, scars, striations and polishes are produced on stone tools used on different materials (such as wood, bone, hide, meat, wild plants, reeds, wild cereals, roots and tubers and domesticated cereals). Different methods of use – cutting, scraping, harvesting and sawing – produce different wear traces. With proper cleaning these traits are visible under light microscopes at magnifications from 100 X to 400 X (Anderson 1980, 1999; Hayden 1979; Keeley 1974, 1980; Korobkova 1981, 1999; Unger Hamilton 1989, 1999; van Gijn 1990 and others). Over the last thirty years this technique has emerged as an important component of lithic research (Odell 2001; Yerkes and Kardulias 1993).

Historical Overview of the Method

Until the 1970's most studies of tool use had to depend on ethnographic analogs of tool forms, which often lack accuracy. With the publication of the English translation of Sergei Semenov's *Prehistoric Technology*, in 1964, a new method (microwear or use-wear analysis) became popular for directly inferring tool use from the microscopic traces of the use and wear left on their edges (Semenov 1964).

S.A. Semenov devised a new methodology based upon the integrations of data coming from experimental reconstruction of tools and contexts, use of ethnoarchaeological comparisons by means of analogy, the comparisons of these data with the direct observation of use-traces on ancient tools (Anderson *et al.* 2005). By developing a new analytical method, Semenov made it possible to distinguish and classify the most common use, wear and manufacturing characteristics of different types of tools (Anderson *et al.* 2005).

In most of his work Semenov used low-power magnification, and different types of microscopes, setting the stage for the research that would follow. He initiated a program of experimental use-wear investigations that involved microscopic examination of chipped stone and ground stone tools. Semenov's exhaustive experimental program was designed to build a comparative collection of utilized tools and to recreate ancient Paleolithic and Neolithic technologies. The English translation of Semenov's method attracted a lot of attention amongst lithic analysts. Inspired by his work, others set out to develop his methods further (including Lawrence Keeley and Ruth Tringham -- her work was continued by George Odell).

In the 1970's Tringham (Tringham *et al.* 1974) and Keeley (1980) refined Semenov's method. Tringham concentrated mostly on 'edge damage' in the form of micro-retouch to be studied with magnification up to 100X. Her work was further continued by Odell (1977) and is commonly known as the 'low power approach.' Keeley, like Semenov, employed incident light illumination polish and repeated use-wear, polishes and other use-damage traces under higher magnification 100X – 400X (which is known as the high power approach). Keeley has inspired a large number of researchers, especially in Western Europe (e.g., Anderson 1980; Anderson *et al* 2005; Juel Jensen 1986; Moss 1983; Vaughan 1981; Van Gijn 1990).

For many years researcher have employed both techniques in their research. The function of a tool is inferred on the basis of several types of wear traces that form on the stone tools when they are utilized. Let us discuss these in details.

Types of Damage

As a result of use several types of damages, are observed on the working edges of the tools including 1) edge-removal, 2) edge rounding 3) striations and 4) micro-polishes.

Edge Removal or Edge Damage

Edge-removal is an important aspect of use-wear analysis. It has been included in Semenov's and Keeley's high-power approach (Keeley 1980: 24 – 25). Keeley classified the edge removal scars according to their general appearance, depth and size. Odell (1975: 232; Odell and Odell 1980: 114–116) has emphasized edge removals and developed a descriptive system for them like shape of the scar, size of the scar, definition

of the scar along its rear border, the distribution of the scarring, and the morphology of the edge.

Keeley (1980) nevertheless pointed out that the problem with inferring tool use on the basis of edge removal alone fails to distinguish the various ways that edge removal can occur. First, these scars can be produced from non–intentional factors during or after its use like intentional re-touching, trampling, transport and soil compaction – and during and after the excavation. This has been proven by several experimental studies carried out by Vaughan (1985). Vaughan showed that micro-chipping and fracturing can occur when the tools are excavated, stored and scattered on the table for analysis and when being re-bagged.

Second, Vaughan's experimental research (1985) has shown that there is far more variability in the location, morphology and distribution of the micro-scarring than the proponents of the low-power approach had suggested. Tringham *et al.* (1974) distinguished longitudinal actions – cutting and sawing – that produces bifacial, discontinuous scarring from transverse actions like scraping, shaving and planing – that correlate with unifacial and continuous scarring. On the other hand, boring or circular movement created trapezoidal scars. Vaughan's experiment (1985) shows that while bifacial scarring is predominant on tools used in longitudinal motions, it was by no means absent on the tools used in transverse motions. He also confirms that transverse actions are not always represented by continuous scars.

Odell and Odell-Vereecken (1980) assert that the morphological character of the scars indicates the relative hardness of the contact material. They formulated four different hardness categories: (a) soft material (meat skin and green leaves) that produce

scars with feather terminations; (b) soft medium (soft wood) that leave large scarring, usually with feather terminations; (c) hard medium (hard woods, soaked antler, fresh bones) that produce hinged scarring of medium to large size; and (d) hard (bone, stone, antler) that leave scars typified by stepped terminations of medium to large size. However Vaughan's study shows that a wide range of scar sizes result from the different material (Vaughan 1985).

Edge Rounding

The second aspect of use damage is edge rounding. Experiments have shown that degree of the rounding can provide some indication of the contact material involved. Hide working, for instance, causes extensive edge rounding. Working on bones, on the other hand, seldom results in rounding. Experimental research, however, (Keeley 1980; Vaughan 1985) has made it clear that one should be cautious about attributing edge rounding solely to use. When a tool is embedded in a sandy matrix or rolled in riverbed, for example, it can become totally rounded.

Polish

Use-polish/micro-polish is one of the most intriguing aspects of functional analysis and the source of a lot of speculation and debate (Anderson 1980; Keeley 1980; Odell 2001; Van Gijn 1990). One of the most compelling issues amongst the use-wear practitioners is the genesis of polish.

What is a micro-polish? According to van Gijn (1990) "a micro-polish is an alteration of the flint surface." A microwear polish is characterized by its localization, extent, texture, contour, brightness and morphology.

Localization of a microwear polish is determined by the contact between the tool and the material worked and is affected by the motion(s) of this contact. The type of contact material, and the duration and intensity of the work determine the extent of a micro-trace. The extent can be marginal, moderate, invasive or spreading/covering (> 1: mm).

Texture is determined by the duration and intensity of contact and by the material worked. Texture is accounted for by the coalescent and non-coalescent spaces within the polish. Texture is differentiated as weak (e.g., butchery); average (e.g., fresh hide); dense (e.g. dry hide); or united/ smooth (e.g. soaked bone).

Polish contour is a characterization of the boundary between the unmodified and modified flint surfaces. The contour at the boundary may be distinguished according to regularly clear (e.g., bone); irregularly clear (e.g., wood); unclear (e.g., soaked bone - grooving); or fuzzy (e.g., dry hide).

Specific contact materials are associated with certain topographical characteristics. Patterns in micro-topography include fluid (e.g., meat cutting); fluid grainy (e.g., fresh hide cleaning); fluid domed (e. g., soft plant cutting), soft grainy (e.g., dry hide scraping); soft smooth (e.g., butchery); hard terraced (e.g., cane sawing); hard platy (e.g., sawing), hard, rounded/domed (e.g., wood, whittling), hard, undulating (e.g., soaked antler) and hard and spreading (e.g., bone, grooving).

The material worked on determines brightness or dullness (that is how much light is reflected). The adjectives "matte," "dull," "greasy," "shiny," and "icy/melted snow" etc., are usually employed. The polish is often interrupted by cavities of variable diameter, by undulations in the micro-topography of the polish and by striae. The orientation of striae can be used for an accurate identification of tool motion (Keeley 1980).

Extensive experiments demonstrated that micro-polish in conjunction with other forms of use-wear – striations, edge rounding, edge removal etc., – is a good indicator of function, especially on fine grained flints and cherts (Anderson 1980; Anderson *et al.* 2005; Fullagar 2004; Gijn 1990; Keeley 1980; Yerkes and Kardulias 1993).

Polish Formation

Despite the long history of research into the use-wear on flint tools, the nature of polish formation is still debated. One of the earliest discussions on polish formation on tools is by Witthoft (1967). He proposes the frictional-fusion model. Why? He argues that the polish formed due to the friction of the stone with the worked surface, causes localized melting of flint surface. Patricia Anderson (1980) expands on Witthoft's (1967) model and proposes that polish formations are caused by dissolution of silica at places of contact on flint surface. The formation of the micro-polishes on the working edges of the tool is the result of the dissolution of tool working edges at the area of contact with worked material. During utilization the cryptocrystalline surface of working edge is transformed into silica gel, which solidifies to amorphous silica. This chemical reaction

possibly involves a combination of factors: the concentration of silica in water, high temperature, pressure, abrasion contact with other silica gel and a certain plant acids.

On the other side of the issue are scholars who declare that polish is exclusively an abrasive phenomenon. Experiments by Yamada (1993) support this position. He examined a tiny portion of progressively utilized siliceous shale to show that the silica gel theory is not operable on that type of lithic material. He argues that if the silica gel theory is operable then the distribution of these micro-features at this locale will change as polish develops; but if abrasive theory is viable then the feature should be gradually smoothed without changing their position. Yamada observed that no deposition of materials occurred and the surface features, which he was using as markers, retained their integrity even after 3,350 strokes.

It seemed that the debate was over when using a particle accelerator and a scanning electron microscope (SEM) connected to an energy dispersive X-Ray spectrometer. Christiansen (1992) indicated that, during use, tiny bits of worked material accumulated in spaces on the surface of the flint. Elements in these bits can be analyzed with the help of the spectrometer. Not only does this add to the depositional theory, but also it offers a direct method for ascertaining materials on which flint tools were worked. But perhaps the situation is more complex than this. Unger-Hamilton (1984) points out that during the utilization, flint surfaces are affected by both mechanical abrasion and depositional factors. One of these factors is likely to be amorphous silica from either the worked material or from the tool itself. Fullagar (1991), attempting through experimentation to correlate amount of silica with kind and amount of polish demonstrates that even small amount of silica may play a significant role in polish

formation and different polishes develop at different rates. The complexities of the situation and the possibility that both mechanical and depositional factors may be at work have inspired researchers to incorporate both models. Mansur (1983) finds that physical abrasion weakens the surface of the tools and mechanically removing the material subsequent attack - when enhanced by water and abrasives result in a thin surface. All theses studies failed to bring about a consensus among the archaeologists on the formation of polish.

Striations

Striations were heavily relied upon by Semenov in his functional analysis. Keeley (1980) relied on the striations mostly for the inference of the motion involved. He classified striations into – narrow deep, deep shallow, broad deep and broad shallow. He concludes that character of the striation results from the presence of abrasive particles between the tools and contact material (Fedje 1979; Kamminga 1979).

Inspired by Anderson's (1980) research on the origin of polishes, Mansur (1983) has arrived at a different theory. Mansur (1983) suggests that silica of the working edge is in a gel state and not a solid state. Thus the abrasive particles must act on a gel and not on the solid cryptocrystalline surface. She also suggests that the appearance of the striations depends on the degree of amorphization of the flint used. As this gel formation is different for different contact material, different striations occur. Mansur discusses the state of the surface of the tool during utilization, with respect to its degree of fluidity and various categories of striation. He creates the following categories corresponding to special types of striation, 1-4. Fluid-gel state almost liquid, with maximum dissolution,

occurs when materials worked are fresh or wet, or with extra silica content (Gramineae, for example). Very few striations form, and any striation grooved in a fluid-gel would immediately vanish. Most of the striations belong to the "filled-in type (Type 4)". Intermediate-gel state midway between solid and liquid corresponds to the work on wood and wet hide. Such striations have a smooth bottom covered with amorphous silica, and are due to a linear deformation of the micro-surface when the scratching particles are dragged along the edge surface. Fullagar (1991) calls these "smooth-bottomed troughs (Type 2)". Solid gel state approaching the solid state, with little dissolution, occurs when the worked materials are dry and tool utilization is of short duration, especially in the work of dry hide. Striations that form have a granular bottom and are due to the removal of crystals from the surface. These have been called the "rough bottomed trough (Type 1)."

The debate still goes on. Recent research has made it clear that striations do not frequently occur due to contact with particular materials. It is becoming clearer that the environment in which the work was carried on was much more influential than the worked material (Moss 1983; van Gijn 1990; Vaughan 1985).

Other Variables in Wear Formation

So far we have discussed the different aspects of damage due to use. Let us now delve into the other factors that determine their developments.

The first is the type of raw material. Raw material is a very important variable. It determines the appearance and formation of the wear traces.

The second important variable is the grain size of the raw material being used. It is not so much the color of the flint but its coarseness that concerns use-wear analysts (van Gijn 1990). The coarser the flint is, the slower the polish formation. The fine-grained flint binds more with water than the coarse ones.

According to scholars (Anderson 1980; Mansur 1983) water and abrasive agents also affect the polish formation. These are the third important variables to be considered. Anderson (1980) for the first time suggests the importance of water or humidity as a variable in the micro-polish formation. She demonstrates that in case of plant working tools; micropolishes were better developed than when materials were in fresh or wet state than dry. On the other hand abrasion of the microsurface and rounding of the working edge are the most important features corresponding to the presence of abrasive agents.

In order to investigate the degree of interaction of both these variables, Mansur (1983) undertook SEM analysis of the experimental tools. The tools were used to work on only one kind of material-dry hide). The experiments show that both the water and abrasive agents are important in microwear formation. Mansur shows that when abrasive agents are not present and all the other variables are kept constant, the amount of dissolution of the tool edge and, thus, the development of the micropolish, are a function of the amount of water present in the material worked. On the specimens analyzed, as well as on other experimental tools used to work different animal and plant materials, micropolishes appeared to form a deposit on the cryptocrystalline surface and were best developed when materials were worked in a fresh or wet state. Under such conditions, the amorphous silica layer provides for the optimal development of the micro-polishes. When the water factor is kept constant, the amount of dissolution increases considerably

upon the introduction of an abrasive agent. As a consequence of this increase, a thick layer of amorphous silica forms on the working edge. These results indicate that, with humidity kept constant, the development of the micropolish varies according to the degree of friction

Another important factor in the use-wear formation is the contact material itself. Experiments have shown that contact materials like siliceous plants, as well as bones produce polish more quickly than roots and tubers, green plants, meat and fresh hide. These soft materials also inflict few edge removal and striations and little edge rounding.

Motion is the final important factor. For example, bone sawing produces heavier polish than bone-scraping. Another critical factor is the duration of work. An additional factor that influences the wear traces once they have developed is the post depositional surface modification. It is thus crucial to assess the extent of the surface modification on the tools studied.

Damage from Natural Causes

A number of natural causes such as compaction of soil, water transport, abrasion from wind borne sediments (Keeley 1980: 30-35) and post-excavation damage also causes polish or patina that sometimes do not allow the polishes from contact material to be differentiated objectively. These wide ranges of phenomena are referred to, by some use-wear analysts as "Post Depositonal Surface Modification" and must be kept in mind while studying the stone tools for use-wear from different activities. Two important ones are Chemical Alteration and Mechanical Alteration.

Chemical Alterations

Chemical alterations can be of many types. They include white and gloss patina.

White Patina refers to a thin layer of whitish coloration covering the tool. This kind of patina is highly reflective and highly porous. According to use-wear analysts this kind of patina is produced by an alkaline environment, usually with a pH of 10.0 or higher (Rottlander 1975 a and b; Schmalz 1960).

Gloss Patina formations occur in acidic environments such as peat layers, with pH layer 4.0 or lower (Rottlander 1975a and b).

Mechanical Alterations

Mechanical alterations include Trampling and Post-Excavation damage.

Trampling refers to the crushing, bruising and breaking of tools by stepping on them. Trampling experiments reveal that they can modify the surface of artifacts to a considerable extent. They can lead to abrasion and also edge damage and, in some conditions, deep scratches and edge scaring (Tringham *et al.* 1974, van Gijn 1990).

Post-Excavation damage can be inflicted on tools during and after excavation or during subsequent analysis. Vigorous sieving on a metal screen produces edge-damage as well as metal-polish. This latter feature, while irremovable, is fortunately very easily distinguishable. Damage can also occur when cleaning the tools for analysis. Contact between the flint artifacts, whether due to being stored together in large bags or due to refitting attempts, causes alterations of the stone tools. The occurrence of extensive edge damage must be carefully studied.

Scanning Electron Microscopy and Energy Dispersive Spectroscopy

Over the last thirty years use-wear analysis has emerged as an important component of lithic research. With the developments in the field, however, several analysts have also realized that use-wears, especially the polish formations, can at times be ambiguous (Brose 1975; Levi Sala 1986). As mentioned above a wide range of post-depositional phenomena such as abrasion by the soil or the acid or alkaline nature of the soil may often hide or alter the wear traces and make functional analysis impossible (Levi Sala 1986). Also the different degrees of freshness of the worked material, the amount of water in it, the time the tool was used, the raw material of the tool and abrasives play important roles in the formation of the microwear polishes and striations (Anderson 1980; Levi Sala 1986; Mansur 1986). Moreover tests have revealed that some activities generate polish formations that are not very well developed (Brose 1975). Here SEM and EDS can help.

Conventional Light Microscope uses a series of glass lenses to bend light waves and create a magnified image. SEM creates the magnified image by using electrons rather than light waves. SEM has a greater resolving power of 3-6 nanometers and a much greater depth of field (.003-1 mm) than a light microscope (.002-.005 nm). At the same magnification level, the diagnostic potential for SEM is much greater than that of the light microscope. These two features – sharpness and depth give SEM a greater advantage and make it possible to define surface textural differences or micro-topography features.

Another advantage of SEM is the ability to apply X-ray analysis with the help of Energy Dispersive Spectroscopy (EDS). EDS is a chemical microanalysis technique.

The technique utilizes X-rays that are emitted from the sample during bombardment by the electron beam to characterize the elemental composition of a sample. Features or phases as small as about 1μm can be analyzed. When the sample is bombarded by the electron beam of the SEM, electrons are ejected from the atoms comprising the sample's surface. A resulting electron vacancy is filled by an electron from a higher shell, and an X-ray is emitted to balance the energy difference between the two electrons. The EDS X-ray detector measures the number of emitted X-rays versus their energy. The energy of the X-ray is characteristic of the element from which the X-ray was emitted. A spectrum of the energy versus relative counts of the detected X-rays is obtained and evaluated for qualitative and quantitative determinations of the elements present in the sampled volume. Some work has been attempted in this area; Anderson (1980) detected the remains of *Ca* and *P* in bone polish and *Si* in plant polish. Christiansen *et al.* (1992) did further analysis and worked with bone, reed and several kinds of wood. They identified *Ca*, *P* in bone, *Si* in reed polish, *Ca*, *P*, *K*, and *Mg* in hazel, *Ca*, *K* and *S* in birch and *Ca*, *K*, *P*, and *S* in the fir, thus showing that every wood polish has a different chemical composition.

Discussion

From the above discussion it is clear that several factors have to be kept in mind before arriving at any interpretation of tool function. Use-wear analysts agree that by a carefully-balanced line of reasoning we can arrive at an interpretation of past behavior. The results of use-wear research conducted worldwide have clearly demonstrated that

information about different kinds of economic and subsistence activities of prehistoric groups can be made on justifiable and scientific grounds from the information retrieved by systematic microwear analysis. Yerkes' research on the microliths from the Cahokia sites, for example demonstrates the microliths were used by craft specialists to drill disc beads (Yerkes 1983). Korobkova (1981), on the basis of her harvesting experiments and the study of ancient sickles tools from Ukraine, Moldavia and Kazakhstan suggests – that it is possible to distinguish between traces of wild grass, domesticated cereals and reeds. Sinha and Grover (1984) studied the changes in stone-tool use at the prehistoric sites of Leang Burung 2 and Ulu Leang 1 in Indonesia. They suggested that the inhabitants of Ulu Leang were better wood workers than the Leang Burung and that their product was more refined. They also suggest a change in the behavior and economic life of the inhabitants between 31,000-19,000 B.P. and 9,000-3,000 B.P. There is indication that the polish from working grasses, as well as plants of the compositae family, is more frequent at Ulu Leang 1. This is attributed to an increase in the collection of wild grains and, probably rice, which are frequently mentioned in the botanical remains from the site. On the basis of a series of experiments using hafted and unhafted tools to harvest wild and domesticate wheat and barley, Anderson (1988) suggests that the analysis of various use-traces on tools allows researchers to make some important distinctions like the distinction between – cutting very green as opposed to ripe cereal, harvesting ears by plucking with a harvesting knife as opposed to cutting bunches of a stem, and harvesting cereals in a tilled field (harvesting cereal grains from tilled soil produce striations and scratches on the tools) as opposed to harvesting cereals in untilled contexts. Following systematic experiments and microwear analysis on blades, Unger-Hamilton (1989) proposed that

emmer and barley were the first domesticates and the southern Levant was the earliest center of cultivation in the world. Donahue *et al.* (2002-2004) suggest, on the basis of their study of the Middle Stone Age points from White Painting Rock Shelter in Botswana – that the points were used as spear tips for hunting small to medium sized animals. The results of the study of the palaeotopography, refitting of the lithic industry and microwear patterns, led Cahen *et al.* to demonstrate the activities being performed at the prehistoric site of Meer (Cahen *et al.* 1979). Microwear analysis on the segments from the Jubilee Center, Transvaal, led Wadley and Binneman to challenge the assumption that segments were used exclusively as stone arrowheads. They propose that the segments were used on vegetal materials such as sedge and wood (Wadley and Binneman 1995).

Use-wear Studies at Bagor

The above-mentioned damages and variables have been considered while analyzing the microliths from Bagor for this dissertation. Use-wear studies of the microliths provided a major source of information about prehistoric life at Bagor. The technique was used to answer an important set of questions:

What were the subsistence and economic activities carried out by the hunter-gatherers at Bagor? OR, what kinds of activities were performed with the tools by the hunter gatherers?

For example, what activities were performed with the blade tools? On the basis of techno-morphology they are assumed to be used as knives for cutting plants or butchering animals. But blades can also be used as scrapers to scrape hides or wood. Similarly, points and triangles are assumed be used as barbs in arrows to hunt animals or as harpoons to fish. But they could also be used for completely different purposes such as sewing hides, or drilling wood or other activities. It is in making these distinctions that use-wear techniques become indispensable. The analysis from this new technology sheds light on the real use — how the stone tools were actually put to use by the hunter-gatherers at Bagor, and what materials they were used on – thereby establishing their actual, purposes. Reconstructing the foraging strategies that were in use at the site before the transition to food production will provides us with a better means of understanding the primary mechanisms underlying the fundamental nature of the economic transition

What were the subsistence and economic activities of the farmers at Bagor? Did the utility of the tools change with the change to food production?

What activities did the farmers perform with the microliths? Or, how did the early farmers use the microliths? Were any of them used to cut or harvest cereals? With the change in economy were some of the tools used for other multiple purposes? For example the blade that was used for cutting meat or scraping hide might be used, with the change in economy, to cut or harvest different kinds of plants and wild or domesticated cereals. Use-wear techniques will help to identify these plant-processing activities at the site.

Methodology

Sampling

Since the number of pieces that can be examined 6 to 8 per day, it is virtually impossible to examine an entire assemblage. For the present research a weighted sample of 300 microlith tools and debitage (150 each from the Aceramic and the Ceramic phases at Bagor) made of chert was chosen from the excavated archaeological materials. Of the 300 tools studied, around 70% were finished tools (from various techno-morphological groups) and smaller percentages, around 30%, were microlithic debitage. This kind of weighted sample has the advantage that the retouched tools, which potentially contain much more information about the prehistoric behavioral patterns (such as economic and subsistence activities), have a higher chance of being examined.

Cleaning Procedures

The microliths for the present study were provided by Dr. Vasant Shinde (excavator of the site). They were excavated under the supervision of Dr. Shinde in 2000-2001. The microliths were collected during the excavation through hand sorting of the dirt by the trained laborers and graduate students of Deccan College, Pune. The microliths are amazingly intact; only 20% of the tools were broken. Dr. Shinde attributes this to the hand sorting of the artifacts (Personal Communication).

The microlith tools were thoroughly cleaned before they were studied. This removed the materials unrelated to use. These contaminants include clay/sediment from excavation trenches, dust from museum shelves, plant material and also handling traces

from lipids to sunscreen. The procedure for cleaning the microlith tools followed Keeley (1980) and van Gijn (1990) with some modifications. Keeley (1980) proposes the use of 10% HCl solution (to remove mineral deposits) and a 20-30% NaOH solution (to remove the mineral deposits). Later he modified the procedure: he substituted KOH for NaOH, as the later proved to dehydrate the flint and often alter the used, polished surface. However researchers (e.g., van Gijn 1990) have refrained from using chemicals altogether because some results from experimental studies indicate the vulnerability of polishes to chemical attacks (Plisson 1983). Use-wear analysts agree on the fact that it is necessary to clean the experimental tools the same way the artifacts are cleaned. So for this study the experimental and excavated materials were immersed in an ultrasonic cleaning tank containing an ammonia-free detergent solution. Successive washes, using clean water, removed small particles of sand, silt and clay adhering to the implement's surface. Apart from initial cleaning, regular cleaning during examination is extremely essential. Alcohol was used during examination to remove finger-grease and grease from the clay supporting the microliths.

Microscopy and Photography

An Olympus BH microscope (with magnification of 50X–400X) was used to study the wear traces. Photographs are an important part of microwear studies. Digital camera systems are better for handling a large number of items because images can be stored in a computer data base, where observation and other records can also be documented and easily retrieved. All the photomicrographs were taken with an Olympus digital camera attached to the microscope. Because Olympus BH microscope uses optics

that uses the compensation method (full corrections only with an objective-eyepiece), the following items were attached to it to take photographs: NFK 3.3X eyepiece, U-V210 Camera adapter, relay lens 0.3X with C-Mount.

Both SEM and EDS analysis for this study was done at the Center of Advanced Microscopy, Michigan State University. The specific microscope used for the study was JEOL 6400 V with a LaB6 emitter (Noran EDS)

Functional Inference

In order to arrive at a functional inference as specific as possible a tripartite data base was used (van Gijn 1990). The first level records variables concerning entire artifacts, pertaining to provenance within the site, typology, morphology, technology and potentially used area, or PUA. PUA is defined by the presence of retouch, edge rounding and polish visible with the naked eye. The second level of information contains a morphological description of each PUA such as edge angle, location of the retouch, form of retouch, secondary modification (e.g., the presence of post–depositional modification and retouch, etc.) and degree of wear. Once defined, each PUA will be examined for the presence of actual wear traces. This level of information allowed for the determination of whether the potentially used area (PUA) was actually used (AUA). The third level of hierarchy contains information on actually used area (AUA), in which the wear traces and their attribute traits are described and interpreted for contact material and motion (Appendix A).

Plant Residue Analysis: Starch Grain Studies

While use-wear analysis does a good job of indicating whether plants were being processed at the prehistoric site of Bagor, it may not be clear from the wear traces alone what kinds of plants were being used. To address this problem starch-grain analysis was integrated into the use-wear research. Combined use-wear starch-grain analyses provide a more reliable reconstruction of the economic and subsistence activities in both hunter-gatherer and food-producing contexts, allowing us the empirical evidence to document the transition.

Historical Overview of the Method

Starch grain may occur in all parts of plants, but they are more abundant in the storage parts like roots and tubers, seeds, fruits, and other fleshy plant structures. Starch granules have been studied for over a century (Esau 1965; Reichert 1913; Schleidon 1849), but only recently has their archaeological and palaeoecological potential been investigated (Atchinson and Fullagar 1998; Barton *et al.* 1998; Fullagar *et al.* 1998; Hall *et al.* 1989; Kealhofer *et al.* 1999; Loy 1994; Loy *et al.* 1992; Lentfer *et al.* 2002; Pearsall 2000, 2004; Piperno *et al.* 2000, 2004; Ugent 1981, 1982, 1984, 1986; Ugent *et al.* 1987). In recent years starch-grain analysis has been used to study human diet, plant use, plant domestication, cultivation and processing, food preparation, ceramic residue analysis and tool use in various parts of the world (Atchinson and Fullagar 1998; Babot and Apella 2003; Barton *et al.* 1998; Fullagar and Field 1997; Fullagar *et al.* 1998; Hall *et al.* 1989;

Iriarte *et al.* 2004; Kealhofer *et al.* 1999; Loy *et al.* 1992; Parr 2002; Pearsall 2003, Pearsall *et al.* 2004; Perry 2004, 2005; Perry *et al.* 2006; Piperno and Holst 1998; Piperno *et al.* 2000, 2004; Ugent 1981, 1982, 1984, 1986; Ugent 1987; Zarrillo 2004; Zarrillo and Kooyman 2006). It has also been employed in environmental reconstruction and land-use studies and in the identification of site activity areas (Balme and Beck 2002; Lentfer *et al.* 2002; Therin *et al.* 1999)

What are Starches?

Starch grains are complex insoluble carbohydrates. Starch is formed by an unknown number of hexose groups and thus is a polysaccharide - $(C6H10O5)_n$. They are microscopic granules (composed of polymers *amylose* and *amylopectin*) that serve as the plants' principal food storage mechanism. Storage starch grains, formed in amyloplasts, are the chief, long-term storage polysaccharide of higher plants. They are found in specialized, plant-storage areas such as underground stems, roots, fruits and the endosperm and cotyledons of seeds (Banks and Greenwood 1975:1; Haslam 2004: 1716; James *et al.* 1985: 162). Distinctive features of storage starch grains are genetically controlled and, when carefully studied, can be used to identify plant taxa (Banks and Greenwood 1975:242; Cortella and Poschettino 1994: 172; Guilbot and Mercier 1985: 240; Loy 1994: 87-91; MacMaster 1964:233; Reichert 1913: 165; Tester and Karkalas 2001: 513; Zarrillo and Kooyman 2006: 484).

Starch grains are formed within the plastid, from a nucleation point, or hilum. Starch grains grow by the accretion of concentric layers of two different types of polysaccharides *amylose* and *amylopectin* around the hilum. These layers are

microscopically visible, and visibility varies with species (e.g. *Cajanus cajun*, Figure 44.1 – 44.3). It is the orientation of *amylose* and *amylopectin* polymers within the granule that imparts quasi-crystalline optical properties upon the starch grain. The most pronounced is the birefringment effect, which produces a visible and distinctive 'extinction cross' when a grain is observed microscopically under cross polarized light ((Banks and Greenwood 1975: 247; Calvert 1997:338; Cortello and Pochettino 194:177; Guilbot and Mercier 1985: 241; Kerr 1959; Loy 1994: 89-90; Radley 1976: 118; Zarrillo and Kooyman 2006: 484). Light passing through the starch grain is deflected, owing to differences in the density and the structure of the starch constituents, and the deflected light rays interfere both constructively and destructively. This interference results in the generation of localized bright and dark regions (e.g. *Cyperus rotundus*, Figure 34.1–34.4). Because the grains are essentially spherical in construction, the polarization is radial. Rotation of the polarizing plate creates the visual effect of the arms of the extinction cross rotating radially around the central crossing point (Loy 1994). This central crossing point is almost always located in the grain hilum (Kerr 1959; Loy 1994: 89-90). This fundamental construction of the starch grain, with its consequent effect under polarized light, is an important characteristic that permits the direct identification of starches in different plants (Loy 1994: 89-91; Cortello and Pochettino 194:177; Zarrillo and Kooyman 2006: 484). Other important attributes such as shape, and size, among others – are also useful in taxonomic determination of the species. Let us look at some of the characteristics in details:

Characteristic Features of Starches

Starch grains can be identified on the basis of overall grain shape, size and composition, the presence or absence of lamellae, the position and form of the hila and surface features such as the presence of the pressure facets.

Grain Shape and Composition

The accretion of the starch grain in the plastid is under genetic control. Thus the difference in the shape and size of the grains are determined by the growth conditions within the cells. The shape of the grains may be spherical, disc, bell shaped, ovoid or elongate. The composition of the grain may be categorized as simple, semi-compound, or compound.

In simple compositions, the individual starch grains are common in a number of plants e.g. *Cyperus rotundus* (Figure 34.1–34.4)

In semi-compound compositions grains are formed by the union of two or more grains surrounded by a common envelope (e.g. *Hyacinthus orientalis*).

In compound compositions consists of aggregates of individual grains without common envelope e.g. *Sesame indicus* (Figure 36.1–36.2).

The Position of the Hila

Starch grains grow by the addition of concentric layers and have a shiny refractive point – hilum, which is their starting point. Depending on the central or the peripheral

placing of the formation center, starch grains are either concentric or eccentric. They are concentric when the hilum is in the center of the starch grain e.g. *Vigna radiata* (Figure 38.1–38.4). They are eccentric when the hilum is removed from the center of the grain, e.g., *Cyperus rotundus* (Figure 34.1–34.4).

The Shape of Hila

They are of various kinds – point (e.g., *Cyperus rotundus*, Figure 34.1–34.4) and stellate (e.g., *Macrotyloma uniflorum,* Figure 41.1–41.6) from the center and branched.

Other Features

Other features like prominent pressure facets (e.g., *Sorghum bicolor,* Figure 46.1 –46.4) also help to distinguish starches of different genera. Another important feature is the presence or the absence of rings on the starch granules known as the lamellae.

Discussion

Starch-grain analysis is a relatively new field and emerging paleoethnobotanical technique. It is thought that starch grains that have become incorporated into cracks and crevices on tool surfaces during processing activities are protected from degradation and thus survive for long periods of time (Loy 1994; Pearsall *et al*. 2004; Piperno and Holst 1998; Zarrillo and Kooyman 2006).

Studies of starches extracted from the lithic implements recovered from archaeological sites – in Australia (Hall *et. al* 1989), in the humid Pacific islands (Loy 1994; Loy *et. al* 1992) and in humid Neotropics (Piperno and Holst 1998) – have made it clear that starch grains can survive for very long periods of time attached to the surface of the stone tools and can be accurately identified. Their preservation is a crucial indicator that starch grain studies can be used widely.

Starch-Grain Analysis at Bagor

In this dissertation starch-grain analysis was used to determine the kinds of plants exploited by the prehistoric settlers at Bagor. The technique was used to answer an important set of questions:

What kinds of plants did the hunter-gatherers exploit?

What kinds of fruits, roots and tubers, vegetables and seeds were exploited by the hunter-gatherers at the site?

What kinds of plants did the earliest farmers at the site use?

Was there a change in the kinds of plants exploited by the farmers at the site? Was there an intensification of plant exploitation at the site? Starch-grain analysis will help to identify the kinds of plants being utilized by both hunter-gatherers and farmers at Bagor.

Methodology

Sampling

Starch-grain analysis was performed on 20 samples (including 15 microlithic tools such as blade and crescents, etc., 2 grinding stones and 3 soil samples) from the Mesolithic period at Bagor. The samples were collected by excavator V. Shinde during the excavation season 2001-2002. Each artifact was carefully lifted by a clean trowel and stored in plastic bags. They were air dried before being sealed and bagged individually. This procedure ensured that microliths were not contaminated with starch residues after use.

Starch-grain analysis was conducted at the National Museum of Natural History, Smithsonian Institute, Museum Support Center under the supervision of Drs. Dolores Piperno and Linda Perry.

Laboratory Equipments and Chemicals

The basic laboratory kit for extracting starches included the following:

1. Beakers (250 and 500 ml) and test tubes (glass and plastic 15 ml each),
2. A centrifuge,
3. The microscopic glassware consisted of high quality Belgian glass with 2mm in thickness, and cover slips,
4. The instruments used for mounting consisted of needles, scoop, forceps, etc,
5. The chemical used was Cesium chloride ($CsCl$) (specific gravity = 1.7900 at 20° C),

6. Reverse Osmosis water was used as a mounting medium.

Extraction of Starches from Artifacts:

Starch grain was extracted from the microlithic tools and grinding stones using the following method:

Step 1: The stone artifacts (microliths and grinders) were shaken in an ultrasonic bath for 10 minutes to completely dislodge adhering sediment and starch. Starch was then isolated by adding a heavy liquid solution of Caesium chloride (CsCl) with a density of 1.8 g cm.

Step 2: The starch was carefully removed and placed in a plastic vial. The vial was filled with reverse osmosis water and centrifuged 3 times at 1000 rpm to remove any trace of CsCl (which can destroy the starches).

Step 3: The starch was water mounted for examination under Zeiss microscope with magnification between 10 – 100 X.

Extraction of Starches from Soil Samples:

Starch grains from the soil samples were extracted by using the following method.

Step 1: 2 g of dry sediment was mixed well with Calcium Carbonate and left overnight to settle.

Step 2: The mixture was centrifuged for 10 minutes and liquid was poured off carefully. To the mixture 1500 μl of aqueous CsCl (specific gravity = 1.7900 at 20° C) was added.

Step 3: The mixture was centrifuged for 10 minutes at 1000 rpm.

Step 4: Some of the supernatant was extracted and placed in 1.5 ml vial. This was repeated again and all the supernatant was extracted and placed in the same vial.

Step 5: The vial with supernatant was filled with reverse osmosis water and centrifuged for 10 minutes at 1000 rpm. The supernatant was carefully thrown off not to disturb the starches that had collected in the bottom. This step was repeated three times to remove any trace of CsCl.

Step 6: 10 μl was removed and mounted on to a microscopic slide.

Microscopy and Photography

After the starches were extracted they were mounted on glass slides and studied under a Zeiss Axioscop 2 plus microscope with an attached camera.

Conclusion

Together lithic use-wear and starch-grain analysis will help to shed light on the transition from hunting-gathering to food production at the Mesolithic site of Bagor, India. To the best of my knowledge this is the first time starch-grain analysis has been used in South Asia. This is also the first time this combined approach has been used in South Asia.

CHAPTER 3

MESOLITHIC SITE OF BAGOR:

THE ARCHAEOLOGICAL SITE UNDER INVESTIGATION

Background

The Mesolithic period is the transitional stage between the Paleolithic and Neolithic periods of human development. They are distributed widely throughout the Indian subcontinent.

Geographical Distribution of Mesolithic Sites

Archaeological research has shown that Mesolithic people settled in different kinds of environments, in this region from the alluvial plains of the Ganges Valley to the cave sites of Sri Lanka and from the Tarafeni Valley of West Bengal to the mountainous regions of the Hindu Kush.

There is an increase in the number of prehistoric sites during the Mesolithic period. According to Misra (2002) several factors may be responsible for this increase and the dramatic rise of population during the Mesolithic period. One of the important factors was the change in climatic conditions such as increased rainfall during the early Holocene period which might have contributed to greater plant growth and increase in the animal population which were exploited by the Mesolithic people. In addition to climatic factors, Misra proposes that the new Mesolithic technology also helped sustain the

population growth. He sees an interaction between climatic conditions and technology; evidence such as increased rainfall during the beginnings of the early Holocene period must have contributed to the greater plant growth and increase in animal populations. This resulted in a subsequent increase in human population due to increased availability of food and technology to sustain it.

Technology

The most important feature of Mesolithic technology is its microlithic industry. Microliths are small tools, 1-5 cm in length hafted on wood or bone (Misra 2002). They are made by removing thin, parallel sided flakes by pressure techniques (Inizan and Lechevallier 1995). The tool types included blades, points, triangles, trapezoids, crescents and scrapers. These microliths were used as components of arrowheads, spearheads (for hunting animals) and other tools such as knives, sickles (for gathering wild plants) and harpoons (hunting fish). Paintings from the rock shelter of Bhimbetka show the use of bows and arrows and the use of microliths as the tips and barbs of arrows. The regular use of bows and arrows must have greatly improved hunting efficiency of the hunter-gatherers and, thereby contributed to an increase in the food supply for Mesolithic people (Misra 2002, pp. 117). Also artifacts such as querns and grinding stones appear for the first time during the Mesolithic period in the Indian subcontinent. They were found at many sites, showing that the food was processed before being consumed (Misra 2002). This most likely increased the nutritive value of the available food and, hence, contributed to better health and longevity of the Mesolithic people.

Subsistence

Knowledge of Mesolithic subsistence is based mainly on the animal remains that were been found in large quantities, very well preserved at the various excavated sites, for the most part. This evidence is also supplemented by the scenes of hunting, trapping and fishing in the rock paintings at sites such as Bhimbetka. The animals most commonly represented in rock art include humped cattle, buffalo, sambhar, chital, gazelle, nilgai, jackal and fox. Paintings at Bhimbetka also show scenes of plant food and honey collection.

Disposal of Dead

The Mesolithic period provides the earliest evidence for the disposal of the dead in the subcontinent. At most of the sites the dead were buried within the habitation area. Grave offerings were made only in a few cases. They included bone and antler earrings and necklaces, bone points and also grinding stones.

Chronology

The chronology of the Mesolithic period is not securely established. The earliest dates belong to Inamgaon c 12,000 B.P. (Misra 2002). A date of 8000 B.P. is known form the site of Sarai-Nahar-Rai in the Ganges valley (Sharma 1980) although its validity is been questioned. From Bhimbetka the oldest date is 7,790 B.P. and 6430 B.P. has been secured from Adamgarh. Even these dates are questionable. Recently a calibrated AMS date of 5700 B.C. has been established for the earliest Mesolithic phase at Bagor (Shinde *et al.* 2004).

The Archaeological Site of Bagor

A large number of Mesolithic sites have been excavated in India (Table 3.1). One of the largest (about 6000 sq. ft.) and the best preserved Mesolithic site in India is the site of Bagor (74° 23' E: 25°21' N) located in Mewar, Rajasthan (Figure 3.1). It is one of the few that is horizontally excavated so as to expose the extensive living floors giving us a detailed account of the prehistoric life (Misra 1973, 1977; MacNeish 1992; Possehl and Rissman 1992; Shinde 2002; Shinde *et al.* 2004).

The Site and its Ecological Setting

Bagor (Figures 3.1) occupies an area of 200 m east west and 150 m north south, with cultural deposits located over an area of about 80 m x 80 m (Misra 1971, 1973; Shinde *et al.* 2004). It is located on the left bank of the Kothari River in the Bhilwara district of Mewar, Rajasthan and lies on a large, prominent stabilized sand dune known as the Mahasati sand dune. A number of palaeo-climatic studies conducted in Western Rajasthan disclose that, although the present environmental conditions in the desert are very inhospitable, they were much better in the past during the Middle and Upper Pleistocene and early and Middle Holocene (Enzel *et al.* 1999; Misra and Rajguru 1989; Singh 1971 and Singh *et al.* 1974). Archaeological research during the last four decades suggests that the antiquity of human settlement in the desert goes back to the Middle Pleistocene (Misra 1989). Several studies suggest that, during the Middle and early Upper Pleistocene, environmental conditions were much better than today (Misra and Rajaguru 1989). There was significant movement of human population in the region

TABLE 3.1: DISTRIBUTION OF MESOLITHIC SITES IN INDIA

SITE NAME	DISTRICT	STATE	REFERENCE
Tilwara	Barmer	Rajasthan	Misra 1971, Lucas *et al.* 1983
Bagor	Bhilwara	Rajasthan	Misra 1971, Misra 1973, Lucas *et al.* 1983 Shinde 2002, 2004
Sarai-Nahar-Rai	Pratapgarh	Uttar Pradesh	Sharma 1973
Mahadaha	Pratapgarh	Uttar Pradesh	Sharma *et al.* 1980
Damdama	Pratapgarh	Uttar Pradesh	Varma *et al.* 1985
Morhana Pahar	Mirzapur	Uttar Pradesh	Varma 1986
Chopani Mando	Allahabad	Uttar Pradesh	Sharma *et al.* 1980
Baghor II	Sidhi	Madhya Pradesh	Sussman *et al.* 1983
Putli Karar	Raisen	Madhya Pradesh	Jacobson 1970
Panchmarhi	Hoshangabad	Madhya Pradesh	Gordon 1950
Adamgarh	Hoshangabad	Madhya Pradesh	Joshi 1978
Bhimbetka	Raisen	Madhya Pradesh	Misra *et al* 1977, Wakankar 1976
Birbhanpur	Burdhawan	West Bengal	Lal 1958
Tarafeni		West Bengal	Basak 1997
Kuchai		Orissa	IAR 1961-1962
Devnimori	Sabarkantha	Gujarat	Malik 1966
Langhnaj	Mehsana	Gujarat	Sankalia 1946 Karve-Corvinus and Kennedy 1964
Akhaj	Mehsana	Gujarat	Sankalia 1946, 1965
Valasana	Baroda	Gujarat	Sankalia 1946, 1965
Hirpura	Baroda	Gujarat	Sankalia 1946, 1965
Amrapur	Baroda	Gujarat	Subbarao 1952
Tarsang	Baroda	Gujarat	Sonawane 1983
Dhek Vadlo	Sabarkantha	Gujarat	Malik 1966
Patne	Jalgaon	Maharashtra	Sali 1989
Pachad	Pune	Maharashtra	Joshi and Bopardikar 1972
Hathkamba	Ratnagiri	Maharashtra	Joshi and Bopardikar 1972
Kiari and Gaik	Ladakh	Ladakh	Otta 1972
Muchchtla Chintamani Gavi	Kurnool	Andhra Pradesh	M. L. K. Murty 1981
Sangnankallu	Bellary	Karnataka	Subbarao 1948, Sankalia 1969

as substantiated by the extensive occurrence of Mesolithic sites such as Bagor, Tilwara, and Dindwana during the Holocene.

The topography of the region is characterized by extensive rocky tracts interspersed with isolated low hills and flat alluvial stretches of cultivable land in the valleys and along the riverbanks (Figure 3.2). It falls in the semi-arid environmental zone located in the shadow of the Aravalli Hills. The area is dotted with stabilized and un-stabilized sand dunes. Much of the area is covered by open woodland of *khedive* (*Prosodies spicier*), *babul* (*Acacia arabica*), *dhal* (*Bait fronds*) and *kauri* (*Phoenix sylvester*) (Figure 3.3). Bushes of *chair* (*Cappers deciduas*) and *ber* (*Sisyphus jujube*) and other wild berries are also common in the area (Misra 1971; Shinde *et al.* 2004). There is not much wild life in and around the area. The only game available consists of deer, fox, jackal, rabbits, birds such as partridge, and sand grouse and some water birds. Agriculture is mostly confined to alluvial stretches along the riverbanks. The annual rainfall is about 75 cm. Numerous tanks, reservoirs and wells provide adequate irrigation for crops such as wheat, sugarcane and cotton.

There are a couple of factors that make Bagor an attractive and strategic location for and must have attracted prehistoric settlers (Shinde *et al.* 2004). The site is located near an arable pastureland (Figure 3.4). The right bank of the Kothari River has a thin cover of coarse, red soil ideal for the growth of pasture (e.g., grass eaten by cattle). Shinde (2004) suggests that "the newly evolving pastoralists and agriculturalists Mesolithic community at Bagor had started domesticating sheep, goat and cattle and thus would have required ample pastureland to be located near the habitation area." Another attraction for the Mesolithic settlers appears to be a large number of rocky outcrops of

quartz (Figure 3.5), which may have provided the Mesolithic people with suitable raw material required for the manufacture of their tools and equipment and for the maintenance of day-to-day life (Shinde *et al.* 2004). These reasons attracted the Mesolithic people to slowly settle here. The excavator (Shinde *et al.* 2004: 392) claims that the area seems to have provided ". . . the area provided the Mesolithic population with wild cultigens of cultivable grass which they collected and utilized for their food requirements." The settlers must have "slowly observed the seasonal changes and innovated the process of incipient agriculture ... and domesticated some of the wild cultigens of the region and settled in the region." The transition is also characterized by the increase in the microlithic blade tool assemblage, circular huts with well-rammed/beaten circular floors, human burials with the habitation and coarse pottery. The presence of food processing equipments like saddle querns, muller, and hammer stones also suggests the beginning of settled life and dependence to some extent on agriculture (Shinde 2002).

History of Research

Excavations 1968-1970

Bagor was discovered in 1967 by V. N. Misra (Deccan College, Pune) and L. S. Leshnik (University of Heidelberg). A preliminary dig at the time revealed the rich potential of the site. The Department of Archeology of Deccan College and the Archeology Department of the State of Rajasthan, under the supervision of Dr. V. N. Misra, jointly carried out the excavations at the site. A compact area of 20 x 10m divided

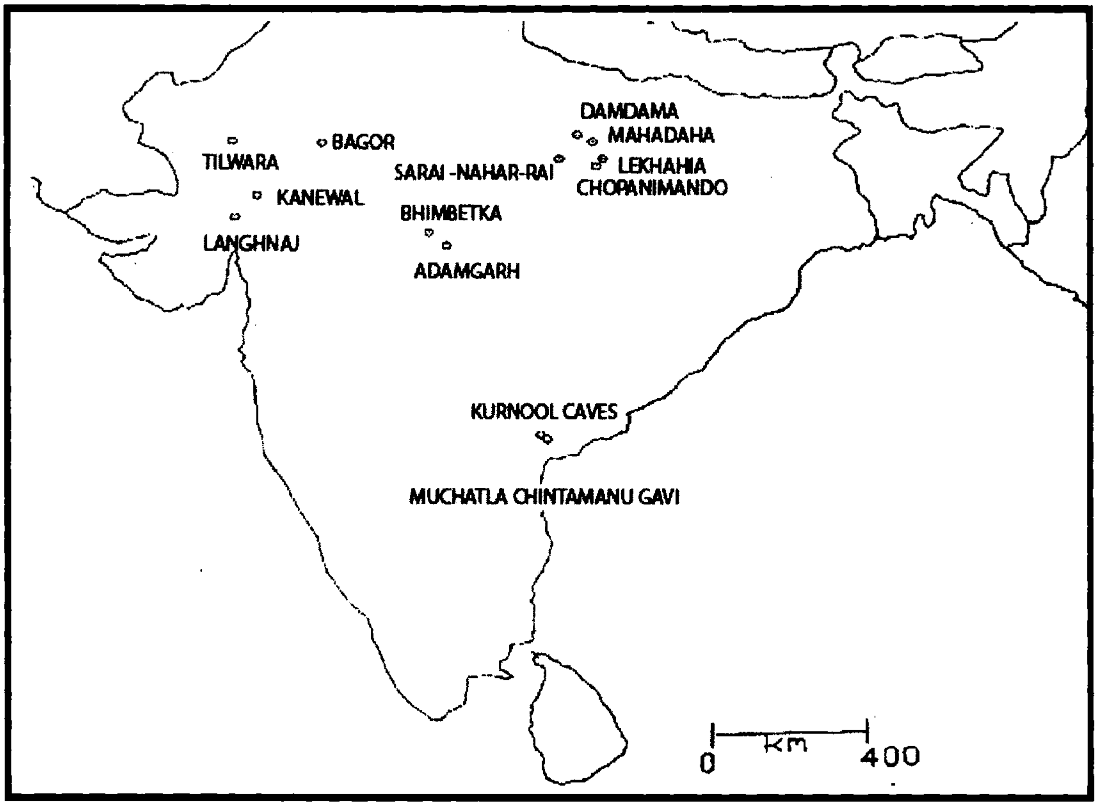

Figure 3.1: Bagor and Other Extensively Excavated Mesolithic Sites in India

Figure 3.2: Bagor's Surrounding Ecological Conditions

Figure 3.3: Pastoralists from the Modern Village of Bagor

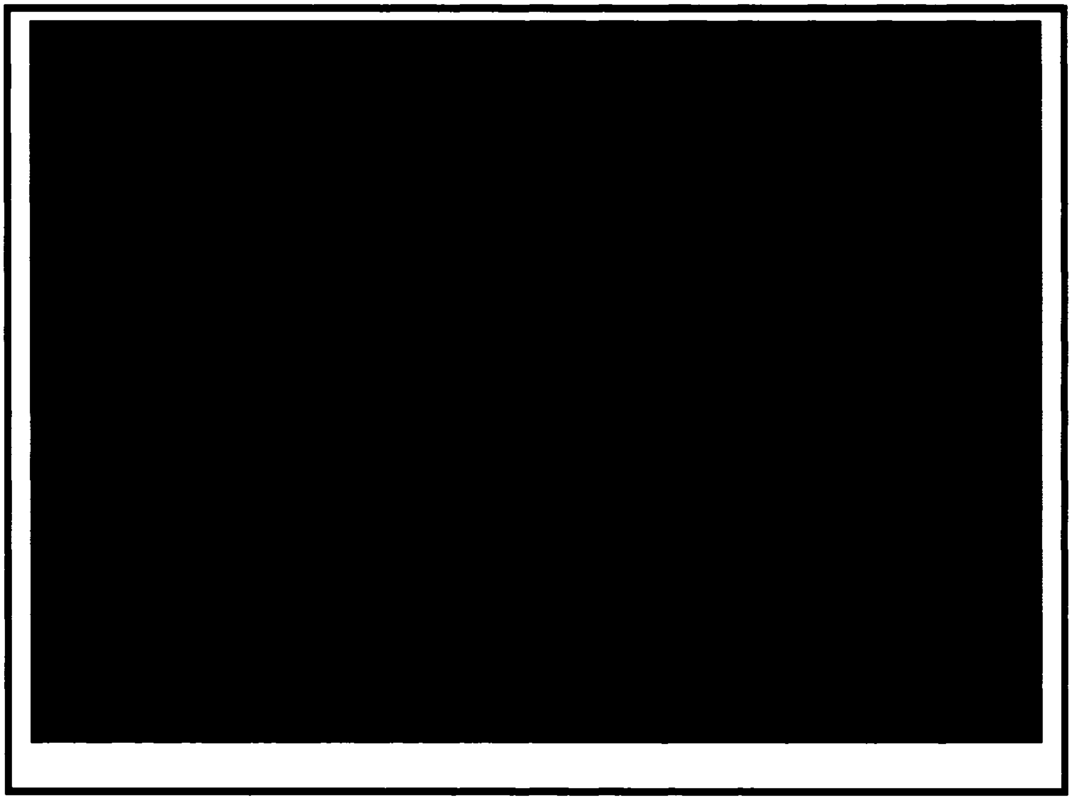

Figure 3.4: Open Woodlands around Bagor

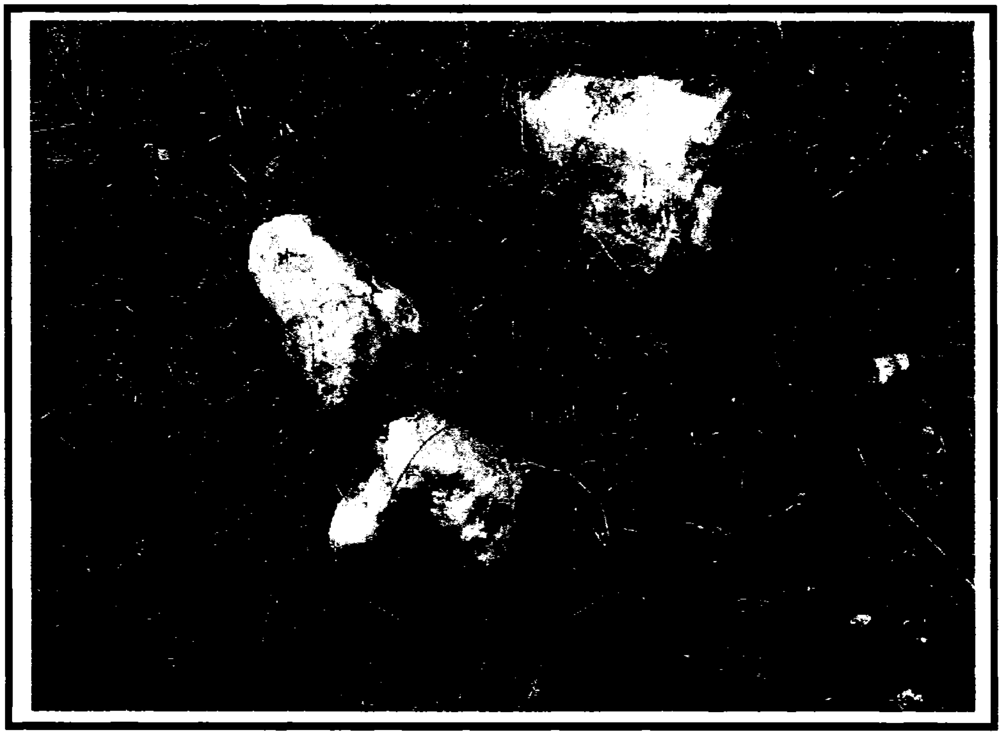

Figure 3.5: Availability of Raw Material

into fifteen trenches, ten of 4m x 4m and five of 4 x 2m was dug in the center and western side of the mound from 1968-70 (Misra 1973, 1977). Five layers were recognized mainly from the changes in the color of the sand (Figure 3.6). These excavations revealed the presence of three successive phases (Misra 1973):

Phase 1 or Mesolithic phase, (5000–2800 B.C.) occupies the lower 50 – 80cm of occupation deposit. Here microliths and animal remains are profuse, and the economy appears to be based on a combination of hunting-gathering and herding of domesticated sheep goat (Possehl and Rissman, 1992; Thomas 1975). People lived in huts with stone paved floors and probably wattle walls. The dead were buried in an extended position laid out east-west.

Phase 2 or Heliolithic phase, (2800–600 B.C.) occupies the next 30-50 cm. Microlithic tools and animal bones begin to decline in quantity as copper and bronze tools make their appearance. The pottery is handmade with incised decoration. The dead are buried in a flexed position oriented east-west. The graves are richly furnished with grave goods – pots, metal tools, ornaments and food offerings. Increased material prosperity implies a more secure and stable economy and suggests the possibility of production of plant agriculture and animal domestication.

Phase 3 or the Early Historic phase, (600 B.C.–200 A.D.) is restricted to the central part of the mound where the occupation was 35–75 cm thick. Microlithic industry declines greatly and animal bones are scarce and highly fragmented. Iron tools come into existence and the pottery is more plentiful and entirely wheel-made.

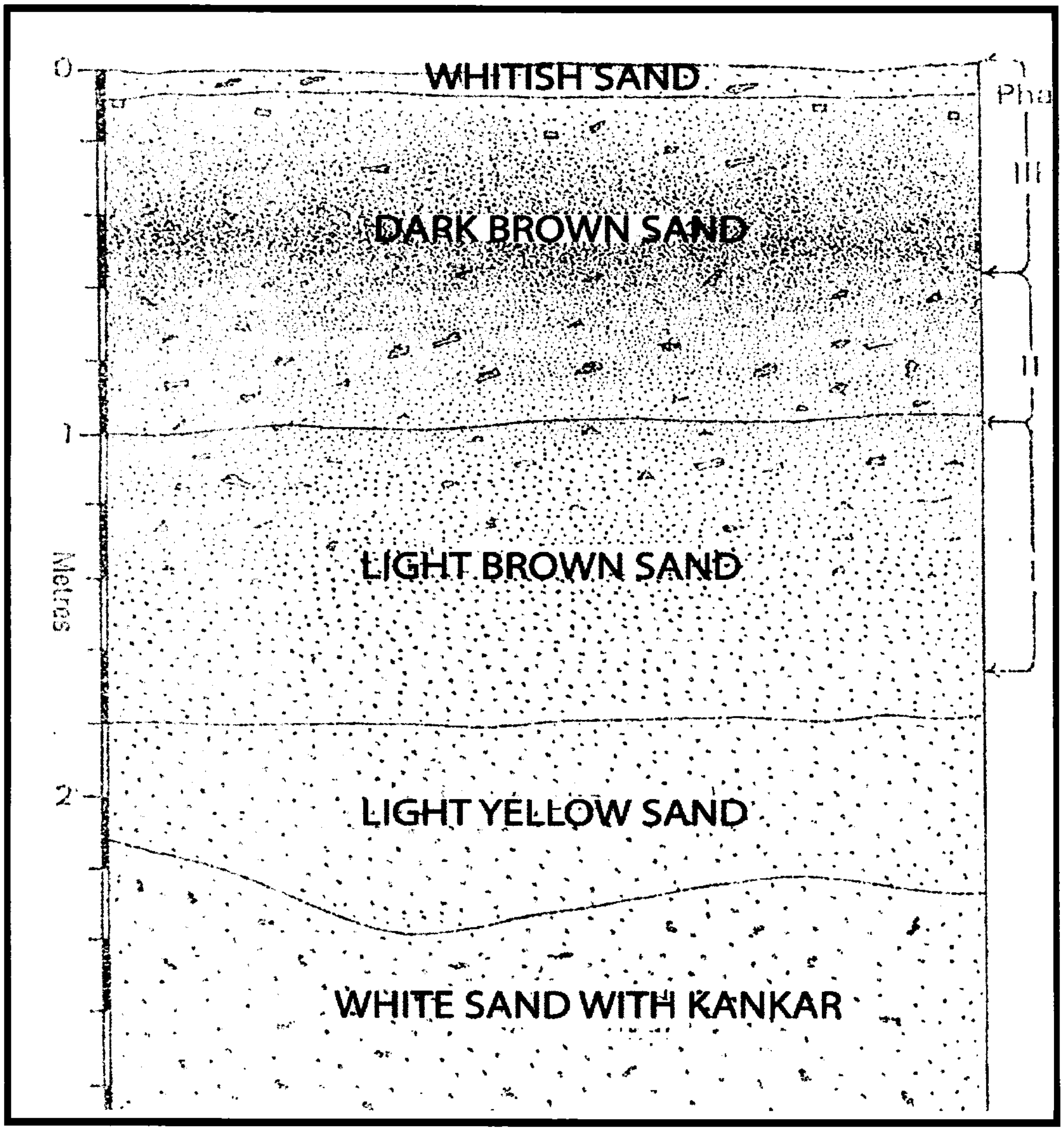

Figure 3.6: Section of the Mahasati Mound (After Misra 1973, Figure 21, pp. 94)

Excavations 2000-2001

However, the 1968-70 excavations were carried out at center of the mound where there was intrusion from the Chalcolithic and Early Historical materials (due to digging by the local villagers) into the Mesolithic phase. This made it difficult to define the Mesolithic phase at the site. To solve this problem, a small-scale excavation was carried out by a research team under the supervision of Dr. V. Shinde in 2000-2001. Considering the aims of the excavations it was decided to follow the vertical excavation method, which provides a complete history of the site and a more detailed cultural sequence. The area close to the earlier excavation on the western edge of the mound was selected for this purpose. This was decided with a view to confirming the sequence of the earlier excavation and the nature of the Mesolithic occupation at the site. The highest point of the mound which is on the northern edge of the earlier excavation was intentionally avoided as that portion contains some late material and also has some modern disturbances (digging by local villagers) on the top.

A long trench measuring 2.5m (north-south) 6m (east-west) was laid in an area which appears to be relatively intact and without later disturbance. This trench was divided into six parts at the interval of one meter. The six divisions of the trench, each measuring 2.5m (north-south) by 1m (east-west), were made to have a better control over the collection of data. This long trench was numbered Trench 1 and the sub-divisions at the interval of 1m were given alphabetical numbers (1A–1F) from east to west. Trench 1A, the first on the eastern side treated as an index trench, was excavated to a depth of 70 cm deep into the virgin deposit.

In all, 5 stratigraphical layers were identified from top to bottom of which the last two, layers 4 and 5, are actually sterile layers. Layer 4 is relatively hard, compared to layer 5. This may be because of the establishment of settlement by the Mesolithic people on top of layer 4. Both the layers are uniformly yellowish in color and look distinctly different from the layers above them, which are the cultural layers. The cultural material is confined mostly to layers 3 and 2. Layer 2 is one of the main cultural layers at the site; it is almost horizontal having a uniform flat surface at the top and base. The layer in general is otherwise quite homogeneous. The average thickness of the layer is 25 cm and contains a few scattered and small fragments of stone, mostly at the base. Layer 3 is loose in composition and light in color as compared to layer 2. It revealed 3 structural phases and a considerable amount of tools, bones and pottery. The top layer 1 is made of humus and surface scatter.

Archaeological Data

The 2000-2001 excavations have brought to light the remains of only the Mesolithic period (unlike the earlier excavation which revealed Mesolithic, Chalcolithic and Early Historic), which were subdivided into two phases Aceramic (cal. years 5700 B.C.) and Ceramic Mesolithic (cal years 4500 B.C.). During this period, a culture based on hunting-gathering underwent a gradual, continuous evolution and developed into a food-producing economy (Shinde *et al.* 2004).

Aceramic Mesolithic

The lower 25 cm of the habitational Layer 3 constitutes the Aceramic phase of the Mesolithic at Bagor. It is dated to cal. years 5, 700 B.C., and has yielded a large number of microlith tools, debitage and bone fragments.

This phase contains the earliest structure found at the site, excavated in trench 1D and 1E (Figure 3.7). According to the excavator Vasant Shinde, it is a dwelling structure (personal communication). "It is difficult" however "to determine the shape of the dwelling but considering the stone alignment it appears to be a circular structure (Shinde *et al.* 2004: 394)". No proper well–made floor levels are associated with the structure, but it is represented by an intentionally made rough, hard compact patch of surface. One post-hole was noticed near the southwest corner of the stone alignment indicating the presence of a superstructure supported on wooden posts. The inner portion of the structure was rammed hard and smoothened whereas there appears to be a stone border along the periphery, possibly to prevent rainwater from entering the structure. The stones may have been used for supporting the posts as a number of stones were found along the post-hole. This structure was at the depth of 60 cm from the surface.

One more structure of a similar nature and contemporary with the earlier was found in the same level in Trench 1B and 1C. The stones in this case are lying haphazardly and therefore its exact plan cannot be determined. This structure has yielded evidence of tool manufacture and food processing. The evidence associated with tool manufacture comes from a large core of quartz with debitage around it. Nearby was found two heavily used rubbing or milling stones made of fine-grained sandstone. Charred animal remains were also found in the structure. It is not likely that the

Mesolithic settlers stayed all year long at the site. According to the excavator, the evidence of flimsy structures suggests that the Aceramic people had a semi-sedentary life, and they occupied the site seasonally.

Ceramic Mesolithic

The Ceramic Mesolithic phase is confined to Layer 2 at the site. It is dated to cal. years 4,500 B.C. (by AMS). It provides evidence of the continuation of the geometric microlithic industry and the structural activity without any drastic change at the site with the exception of the appearance of large amounts of handmade red and grey pottery. This pottery is different from the previously known ceramic assemblages in this region. It is coarse, brittle, clay tempered with grass and sand, ill-fired and plain. The red ware is decorated with incised criss-cross patterns. This is the earliest evidence of potsherds in this region (Shinde *et al.* 2004).

Two structural phases were identified in the Ceramic Mesolithic phase (Figure 3.8). The first phase has a patch of well-rammed/beaten circular floors, but unlike the Aceramic phase structures there are no stone alignments on the periphery (Shinde *et al.* 2004). The floor of the structure covers an area of 2.5 m x 2.5 m. According to the excavator, V. S. Shinde, this structure was a domestic and manufacturing unit. The evidence of manufacture of stone tools consists of cores, debitage and finished tools scattered over the floor. The evidence of the dwelling consists of animal bones (including domesticated cattle, sheep and goat) and heavily used rubbing or milling stones. The second structural phase of the Ceramic Mesolithic phase

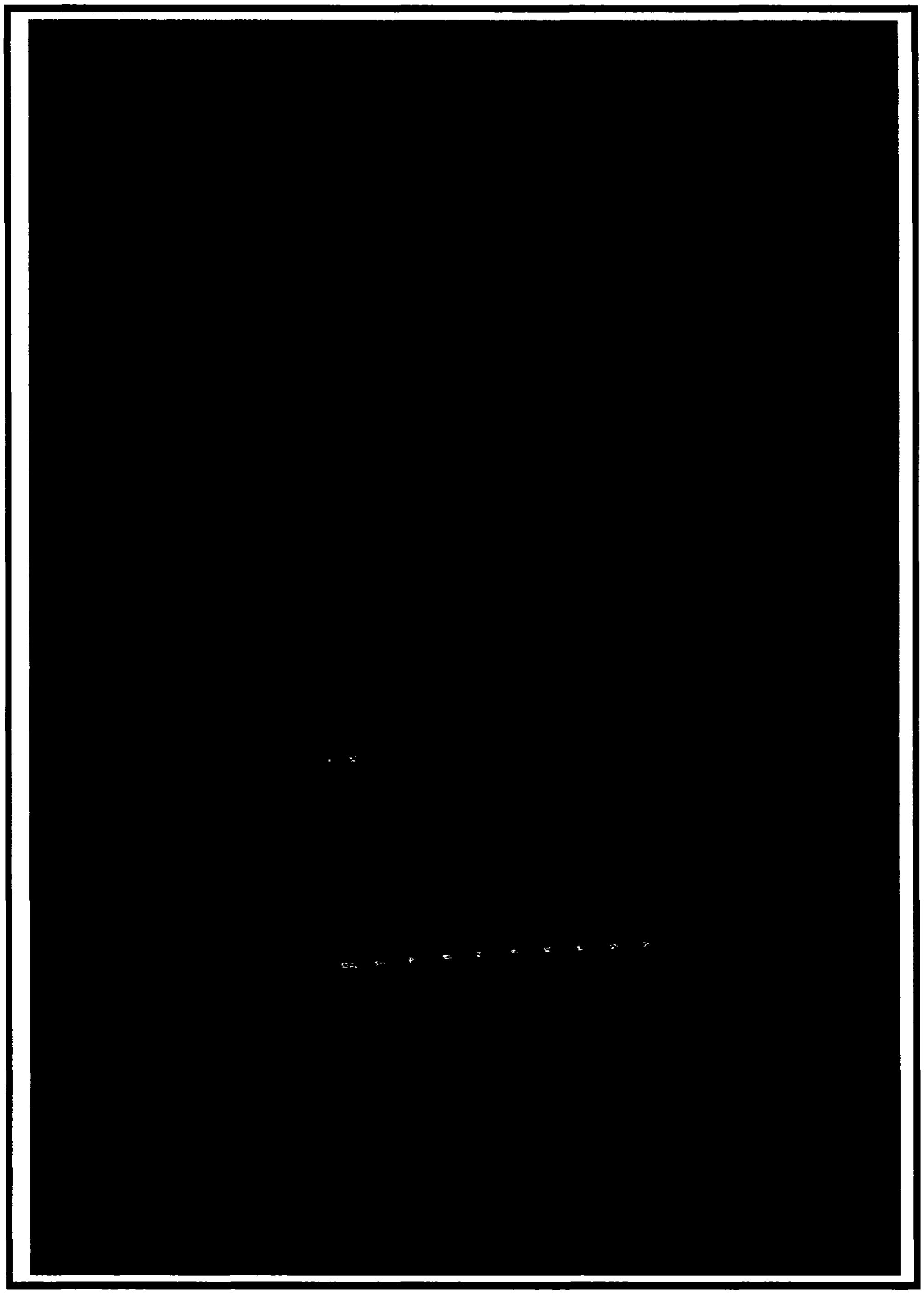

Figure 3.7: Residential structures from Aceramic Phase at Bagor (Shinde *et. al* 2004, Figure 7, pp. 394)

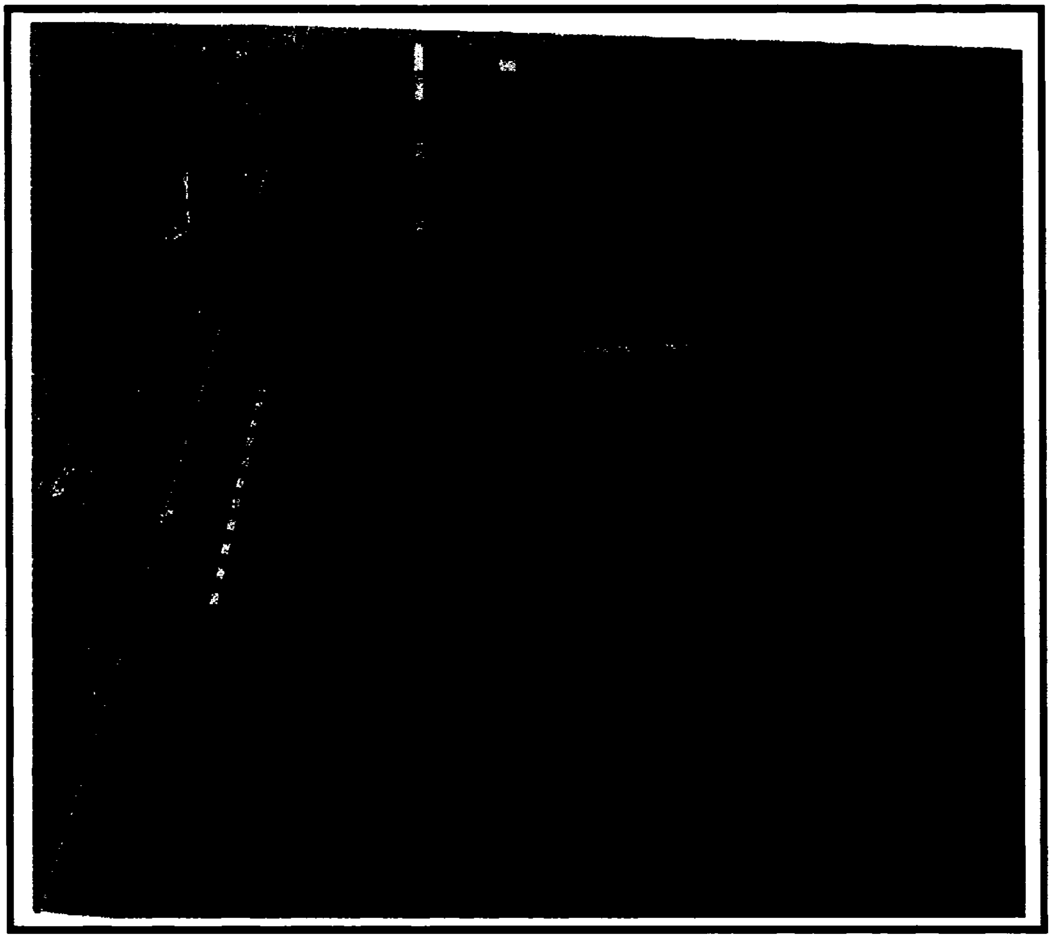

Figure 3.8: Structural Remains in the Ceramic Phase at Bagor (Shinde *et. al* 2004, Figure 7, pp. 393)

is represented by a well-rammed floor with even distribution of pottery and bones inside the structure. The evidence of mud structures, coarse pottery, food processing equipment, and microlith tools and debitage suggests that Mesolithic people lived a sedentary life.

Subsistence

A large number of animal bones were also found *in situ* on the working and living surfaces. The species (Table 3.2 adapted from Thomas 1975, pp. 325) identified after the 1968-1970 excavations (although there is a lot of controversy on whether most of the animal remains identified at the Indian sites are correct identification see Meadow 1996, pp. 392,) include cattle (*Bos indicus* L.), domesticated sheep/goat variety (*Ovis orientalis vigne*i Blyth race domesticus and *Capra hircus aegagrus*), pig (*Sus scrofa cristatus*), buffalo (*Bubalus bubalis* L.) wild animals include a variety of deer including– sambar (*Cervus uniolor*), chital (*Axis axis*), black buck (*Antilope cervicapra*), wild boar (*Sus scrofa*) and jackal (*Canis aureus* Linn) present in the Mesolithic phase (as reported by Misra 1973, 1977; Thomas 1975). Evidence of exploitation of tortoise and fish remains was also found at the site (Misra 2002; Thomas 1975). The faunal remains from the 2000-2001 has not yet been studied.

The presence of food-processing equipment suggests incipient agriculture. M.D. Kajale has collected soil samples to study the macro-botanical remains at the site; however the results of the study are still awaited.

TABLE 3.2 FREQUENCY OF ANIMAL BONES FROM THE MESOLITHIC PHASE AT BAGOR (After Thomas 1975, Table 1, pp. 325)

Species	Phase I or Mesolithic	%
Ovis oreintalis vignei	1143	64.43
Capra hircus aegagrus		
Bos indicus	278	15.67
Sus scrofa cristatus	66	3.72
Bublaus bubalis	14	0.79
Antilope cervicapa and,	79	4.45
Gazella gazelle		
Axis axis	85	4.79
Cervus unicolor	76	4.29
Lepus cf. nigricollis	10	0.56
Vulpes cf. bengalensis	09	0.51
Herpestes edwadsi	14	0.79
Total	**1774**	

Microlithic Industry

Both the 2000-2001 and earlier excavation at Bagor produced large amounts of finished and unfinished microliths – small stone tools hafted into handles and shafts. Excavators so far distinguished around forty types of microlith tools – blades, points, crescents, lunates, triangles, burins and scrapers. A large number of retouched and unretouched flakes were also found at the site. They are small geometric shaped tools ranging from 40-20 mm; some are even smaller (between 5-10 mm) (Khanna1995; Misra1971, 1973; Shinde *et al.* 2004).

The raw material is predominantly quartz. It ranges in quality from dull white opaque to bright translucent crystalline variety. About 3 percent of the tools are made on chert. Few made on chalcedony were also found (Khanna 1989, 1995). Chert is of many colors and includes both fine and coarse varieties, but the former are predominant. The actual retouched tools were made mainly on chert; a few retouched quartz tools were also found (Vasant Shinde: Personal Communication).

The raw material quartz is easily available in veins in the rock outcrops of the riverbeds. Chert and chalcedony are also available in the quartz veins (Misra 1977).

Technique

The microlithic tool industry consists of tools based on production of blades. The incidence of flake tools is very small. Blades were produced from small prismatic cores of cylindrical or pyramidal shape. Blades are long, narrow and strictly parallel-sided and speak of a sophisticated blade-production technique. The retouches were done by pressure-debitage technique. M. L. Inizan and M. Lechevallier (1995), who studied

the technology at Bagor after the 1968-1970 excavation, have suggested that the pressure debitage technique was fully mastered by the Mesolithic people at the site.

The microwear analysis of the microliths done by the author suggests that they belong to a certain stage of this technical tradition, when metal (in this case copper) was introduced in pressure debitage. Three hundred microliths (from the 2000-2001 excavation) belonging to the Mesolithic phase (Aceramic and Ceramic) at Bagor were studied under light microscope for microwear analysis. Three tools -- one from the Aceramic and two from the Ceramic phase – provide visual evidence of what seems to be copper metal when studied under the magnification of 400X under light microscope (Figure 3.9 and 3.10).

In all the three cases the copper traces were concentrated on the retouched edges of tools. The belief that the residue was copper was based on similarity between the color of the residue (greenish blue) and the color of the known copper residues. In order to establish that the trace was copper a more detailed analysis–using a Scanning Electron Microscope (SEM) and Energy Dispersive Spectroscopy (EDS) – was undertaken (Figure 3. 11).

Both SEM and EDS analysis for this study was done at the Center of Advanced Microscopy, Michigan State University. The specific microscope used for the study was JEOL 6400 V with a LaB6 emitter (Noran EDS). Spectra from the residue on the blades were analyzed to determine their chemical composition. Residue of copper, silicon, oxygen, aluminum, zinc and carbon were found in the spectra (Figures 3.12, 3.13 and 3.14).

Residue of *Cu* opens a wide array of questions on how, why and where it is coming from. Because of the proximity of the site to the Aravalli Hills (which was mined for copper during the prehistoric period), it was important to determine if the copper residue is a naturally occurring part of the raw material or is, in fact, a residue from the use of copper. Dr. Duncan Sibley (personal communication), a geologist at Michigan State University, was consulted, and he suggested that a sample should be sent to Michael D. Glascock at MURR (Archaeometry Lab, Missouri University Research Reactor) for a Neutron Activation Analysis. NAA would help to find out if copper is present in the chert matrix. Dr. Glascock (MURR, Personal communication: email) suggested that sensitivity for copper by NAA at MURR is not good enough. Laser ablation ICP-MS (Inductively Coupled Plasma Mass Spectrometry -- which is another technique to determine trace-elements) could be used to measure copper in the chert. This technique removes the copper while ablating, thus the copper signal is non-reproducible. For this reason the SEM technique, Dr. Glascock suggested, is therefore a better way to study the surface of the microlithic tools. In addition, to compare the copper on the retouched edges of the chert artifacts and the chert matrix, a saw is used to cut into the chert stone and expose the interior to see if it has copper. New tests were conducted. One of the microliths (with the permission from the excavator) with copper residue was cut into two halves and the matrix was studied. No evidence of copper was found in the internal matrix of the chert. This suggests the fact that copper was not part of the raw material (Figure 3.15).

One important observation during the study was that copper residue becomes concentrated on the retouched edges of the tools. Several experiments were conducted to

reproduce the traces like those found on the microliths. It was found that while retouching, if the copper tool was used efficiently, the metal residue is removed along with the debitage. Because of the small size of the blanks the strength required to retouch is also minimal. However, precision in the application of the point near the edge of the bladelet butt (which in some bladelets is sometimes thick and facetted) is difficult and, in some occasions, the copper tool slipped off the removed debitage onto the tools, thus leaving a small trace on the worked surface. Microscopic examination of the replica microliths revealed that, on those occasions, the metal tool had left a small trace of copper on the worked surface. It is possible that this happened even when the very skilled toolmakers were retouching the microliths during the prehistoric times some traces such as one we have found were made accidentally and amongst them only few have survived through time.

Microlithic Tools Studied

A total of 300 (150 from Aceramic and 150 from Ceramic phase) microlithic tools were studied from the 2000- 2001 excavation (Table 3 – 6, Appendix C and Appendix D). The sample studied included around 70% (of the 300 tools studied) retouched chert tools and the rest (30%) were unretouched blades/blanks and flakes. The following types were studied – retouched blade, points, triangles, crescents, burins, scrapers and debitage (including blade perform and unretouched flakes).

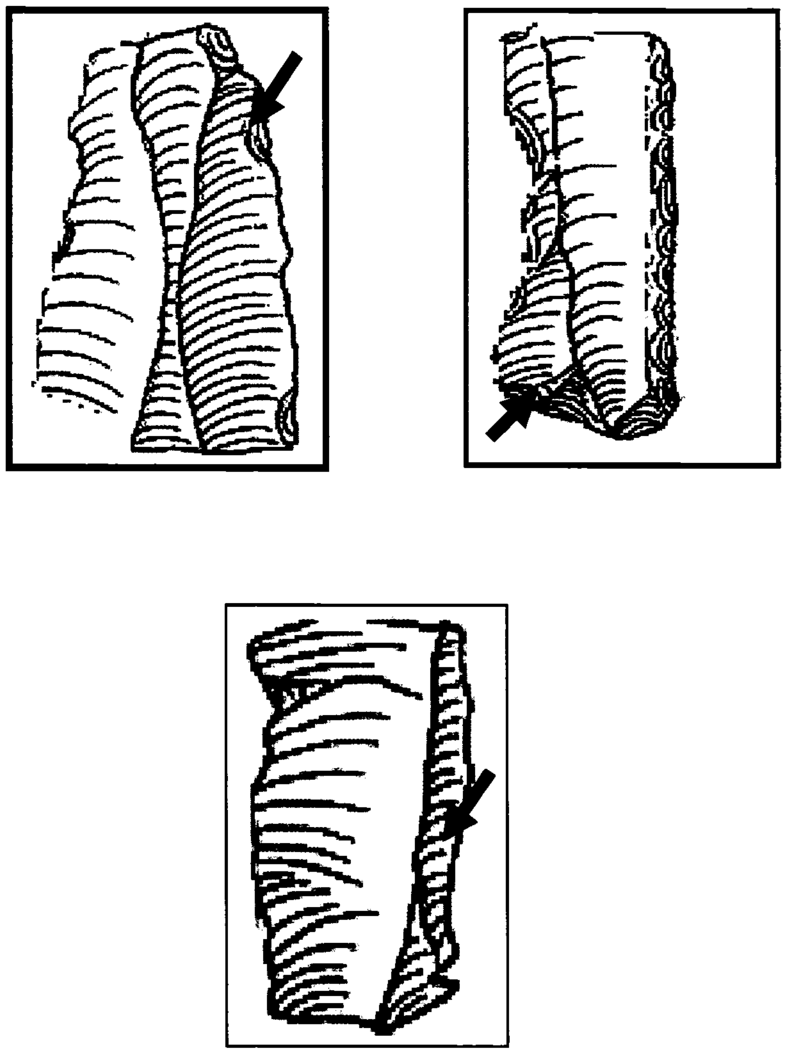

Figure 3.9: Schematic Representation of Tools with *Cu* Trace

Figure 3.10: Copper Residue under Light Microscope

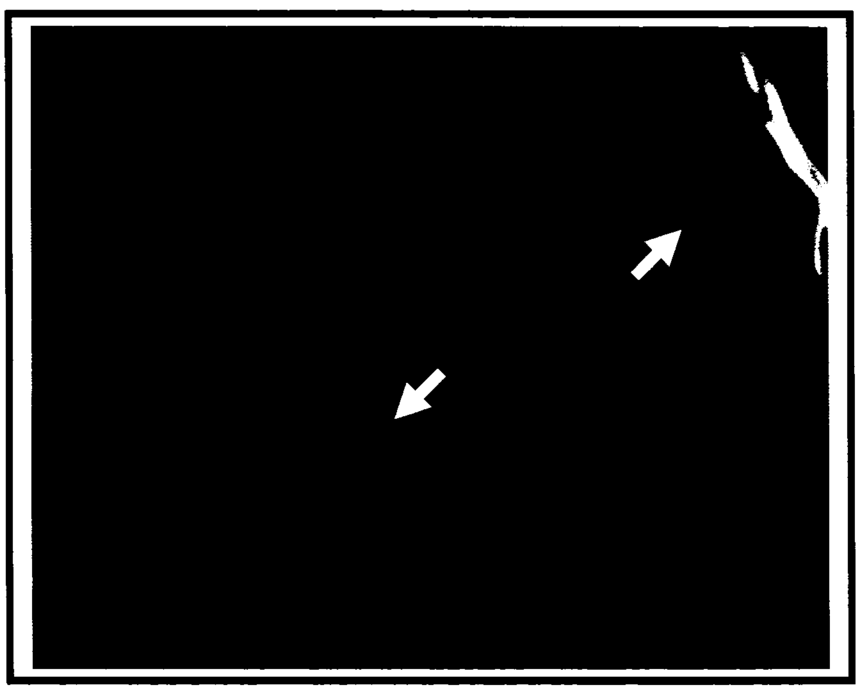

Figure 3.11: SEM Image of Copper Residue on Microliths from Bagor (Residue Shows as a Series of White Area)

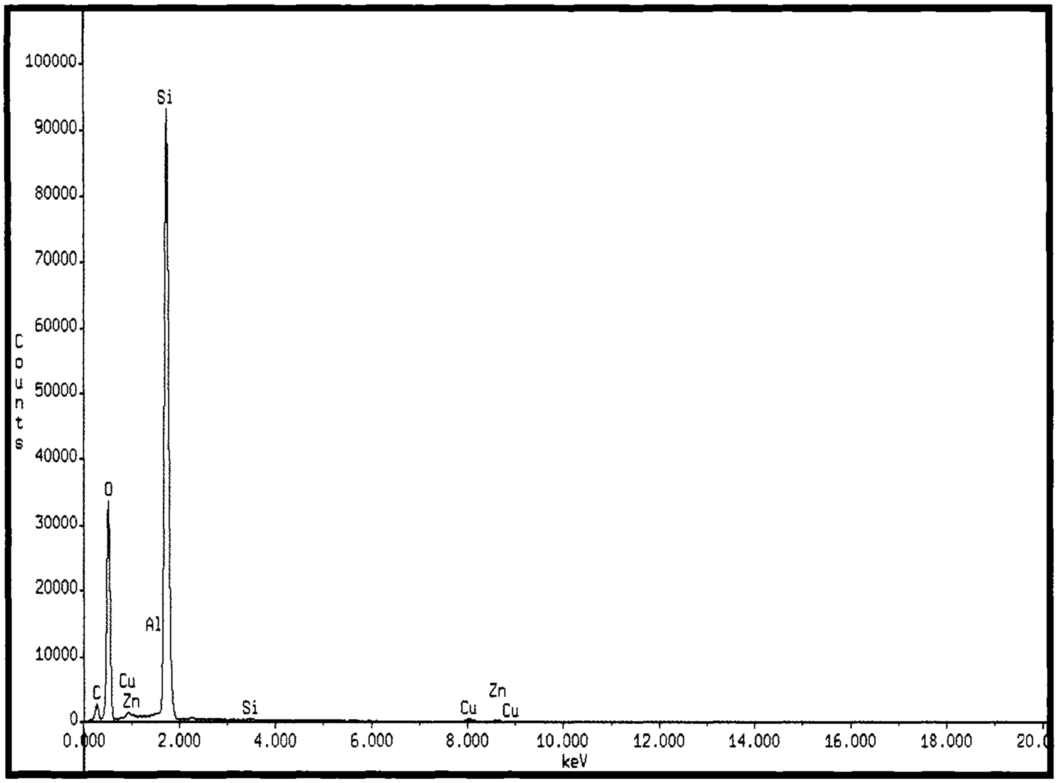

Figure 3.12: EDS Spectrum of Blade I

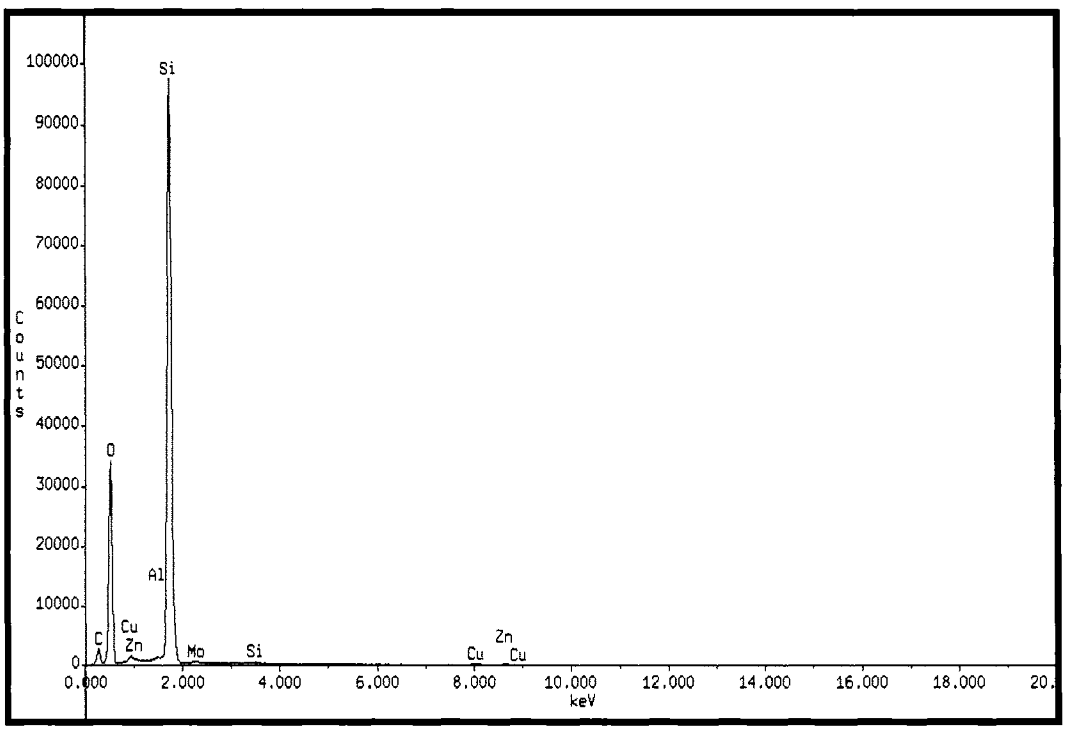

Figure 3.13: EDS Spectrum of Blade II

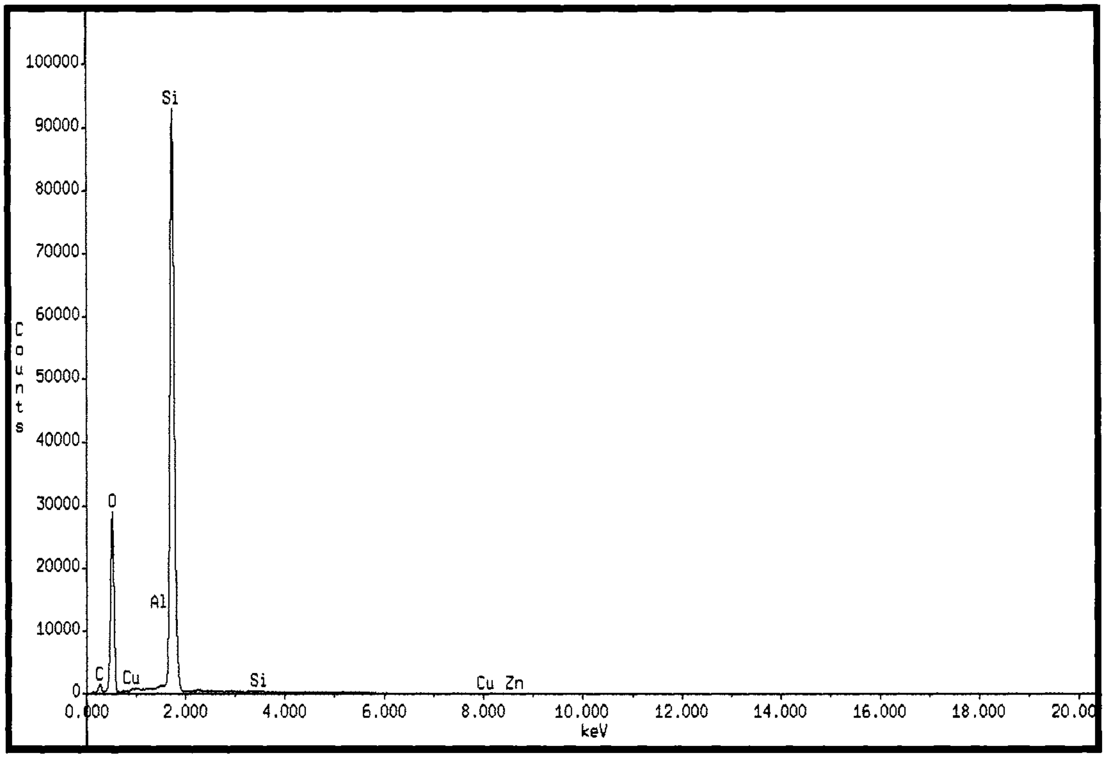

Figure 3.14: EDS Spectrum of Blade III

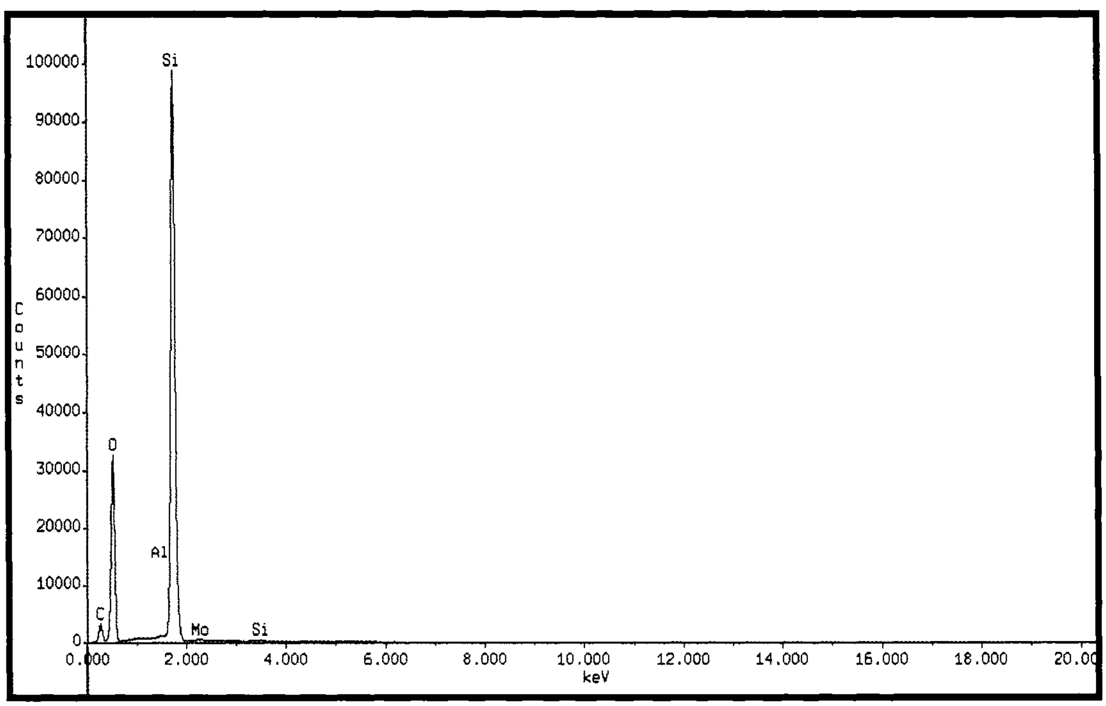

Figure 3.15: EDS Spectrum of Chert Matrix of Blade Tool I

Unretouched Tools

Blades Blanks: They were found in large numbers. Twenty blade blanks were studied from the Aceramic phase. The mean length, breadth and thickness of the unretouched blades from the Aceramic phase were 15.61 mm, 6.83 mm, 1.90 mm respectively. From the Ceramic phase 18 blade blanks were studied. The mean length, breath and thickness here were 13.36 mm, 6.05 mm, 1.90 mm respectively.

Unretouched Flakes: Ten unretouched flakes from each phase were also studied. The mean length, breadth and thickness of the unretouched flakes were 12.67 mm, 6.32 mm and 1.65 mm and 13.92 mm, 7.44 mm and 2.08 mm respectively.

Finished Tools

Blades: Blades are the most common type among the finished tools. They were produced from small prismatic cores of cylindrical, pyramidal or squarish shapes. Blades are long, narrow and strictly parallel. Fifty three blade tools were studied from the Aceramic phase. The mean length, breadth and thickness were 15.98 mm, 6.40 mm and 1.98 mm respectively. Sixty five tools were studied from the Ceramic phase. Here the mean length, breadth and thickness were 14.39 mm, 5.69 mm and 1.90 mm.

Crescents: All of these occur in the Ceramic phase (this appears to be a very significant difference; however, it might be a product of sampling errors which was uncontrolled by the author as she studied the tools that were provided to her by the excavator at the time of the study). They are half moon shaped. Most of the tools are symmetrical in that both ends of the tool are pointed and maximum width lies in the center. The arch is steeply blunted in all the crescents; some are retouched on the chord.

Twenty-nine crescents were studied from the Ceramic phase. The mean length, breadth and thickness were 17.85 mm, 4.88 mm and 2.31 mm.

Points: These are blades that have been retouched to form a pointed tip at one end. A total of 37 points from the Aceramic phase and 10 points from Ceramic phase were studied. The mean length, breadth and thickness were 16.16 mm, 4.58 mm and 1.85 mm for the Aceramic points and 14.88 mm, 4.51 mm and 1.76 mm respectively for the Ceramic tools.

Triangles: This is another common type among finished tools. Seventeen triangles were studied from the Aceramic phase. Five were examined from the Ceramic phase. Two types are common isosceles and scalene. The mean length, breadth and thickness were 17.79 mm, 6.19 mm and 1.96 mm in the Aceramic phase and 13.95 mm, 6.64 mm and 1.96 mm in the Ceramic phase.

Others

Scrapers: A total of 15 (13 = Aceramic and 2 = Ceramic) scrapers was studied. The majority (N=7) of the scraping edges were created on the distal ends of the blades. In addition 3 end scrapers on flakes were studied. Lastly, 2 artifacts exhibited retouch on more than one edge were studied; such tools are called multiple scrapers. The mean length, breath and thickness were 21.01 mm, 14.40 mm and 4.55 mm in Aceramic phase and 16.86 mm 8.01 mm and 3.49 mm in the Ceramic phase.

TABLE 3.3 – BAGOR ACERAMIC TOOL TYPES STUDIED

Tool Type	N%
Retouched Blades	53 (35.3%)
Unretouched Blades/Blanks/Preforms	20 (13.3%)
Unretouched Flakes /Debitage	10 (6.6%)
Triangles	17 (11.3%)
Points	37 (24.6%)
Scrapers	13 (8.6%)

TABLE 3.4 – METRICAL ATTRIBUTES OF ACERAMIC TOOL TYPES

Tool Type	N	Mean Length	Mean Breadth	Mean Thickness
Retouched Blades	53	15.98	6.40	1.98
Unretouched Blades	20	15.61	6.83	1.90
Unretouched Flakes	10	12.67	6.32	1.65
Triangle	17	17.79	6.19	1.96
Points	37	16.16	4.58	1.85
Scrapers	13	21.01	14.40	4.55

TABLE 3.5 – BAGOR CERAMIC TOOL TYPE STUDIED

Tool Type	N%
Retouched Blades	65 (43.3%)
Unretouched Blade	18 (12%)
Retouched Flakes	10 (6.6%)
Unretouched Flakes/Debitage	11 (7.3%)
Triangles	5 (3.3%)
Points	8 (5.3%)
Scrapers	2 (1.3%)
Burins	2 (1.3%)
Sickles/Crescents/Lunates	29 (19%)

TABLE 3.6 – METRICAL ATTRIBUTES OF CERAMIC TOOL TYPES

	N	Mean Length	Mean Breadth	Mean Thickness
Unretouched Blades	18	13.36	6.05	1.90
Unretouched Flakes	10	13.92	7.44	2.08
Retouched Flakes	11	13.01	9.50	2.13
Retouched Blades	65	14.39	5.69	1.90
Triangles	05	13.95	6.64	1.96
Points	08	14.88	4.51	1.76
Scrapers	02	16.86	8.01	3.49
Burins	02	15.84	8.50	2.80
Crescents	29	17.85	4.88	2.31
Total	**150**			

Retouched Flakes: These include the retouched flakes type. A few flake implements without bulb of percussion or other indication of impact were also retouched. Eleven tools were studied from the Ceramic phase. The mean length, breadth and thickness were 13.01 mm, 9.50 mm and 2.13 mm respectively.

Discussion

The site of Bagor adds significant information to the reconstruction of the Indian Mesolithic. The secure AMS dates from the two Mesolithic phases at the site has helped establish the chronology of the Indian Mesolithic and makes it the index site for the Mesolithic sites in western India. This study along with the future study and publication of the fauna and the macro-botanical remains at the site will provide major information on the life-ways of the Mesolithic people in India.

CHAPTER 4

ACTIVITIES AT THE MESOLITHIC SITE OF BAGOR: RESULTS OF USE-WEAR ANALYSIS

Introduction

Stone tools are among the most common finds made by archaeologists working at prehistoric sites. They therefore form one of the major sources of information about prehistoric life. As mentioned in Chapter 3, use-wear study (the microscopic study of the wear patterns) on the working edges of stone tools has proved to be a productive method of determining stone-tool use in archaeology (Anderson 1980; Becker and Wendorf 1993; Binneman 1997; Keeley 1980; Schreurs 1992; Wadley and Binneman 1995 and van Gijn 1990). Stone-tool function helps us to learn a great deal about precise subsistence and economic behavior of prehistoric peoples.

For this dissertation research 300 microlithic tools from Bagor (150 each from the Aceramic and Ceramic Mesolithic phase) were analyzed for use-wear to answer questions related to the subsistence and economic activities of the hunter-gatherers and the farmers at the site (See Chapter 1, 2 and 3 for details) as reflected by the microlithic artifacts. By determining the activities performed with these tools, it is believed that the nature of transition at Bagor could be reconstructed with greater accuracy.

Experiments

Experiments are a very important part of use-wear research. They serve as the reference collection or control variable. Most use-wear analysts begin by setting up an experimental program. Experiments conducted provide controls for variables such as raw material, form of tools, type and state of contact material and intensity, direction and duration of activities. When subsequently examining an archaeological assemblage, the experimental research data help to identify the areas of use and to establish a basis for interpreting the contact materials, as well as the activities performed in the prehistoric past.

Since no experimental studies have been conducted in India before studying the archaeological samples from Bagor, many experiments needed to be made (in all, 50 experiments were conducted, Appendix B). The determination of stone-tool uses – in terms of contact material and tool motion/actions – was based on a program of experimental tool manufacture and use modeled after and developed by Keeley (1980), van Gijn (1990) and Vaughan (1985). The experiments involved cutting meat, fish, fruits, cereals and wild plants, scraping fish scales, hide and roots and tubers and drilling hide, wood and bones (Appendix B, See Figures 1-4). Other tool experiments – such as shooting in the ground with a projectile, cutting sod, boring and piercing wet and dry pottery and trampling were also done. The use-wear on these tools was used as control samples to understand the traces on microliths from Bagor (Appendix B, See Figures 5-18).

Use-wear analysis of Aceramic Phase Microliths

While the basic data can be reviewed in Tables 3.3 – 3.4, a brief description of the artifacts will also be presented here. As mentioned before, a total of 150 microliths made from chert provided by the excavator (V. Shinde from 2001-2002 excavation seasons) was studied from the Aceramic Phase of the Mesolithic period to examine the use and activities performed with the tools (Figure 4.1, Appendix C). The analysis also helped to determine the relation between the tool techno-morphology and tool use. The dissertation study sample included the following groups:

Retouched blades

Fifty-three (35.3% of the total 150 tools studied) retouched blades were studied. Blunted-backed blades are common. One margin of the blades is steeply blunted (this side is usually hafted into wood or bone) and the other edge is retouched and used as a working edge.

Triangles and Points

Seventeen triangles (11.3%) were studied. The types included isosceles and scalene triangles. A total of thirty-seven points (24.6%) was studied. They are thin blades retouched to form a pointed tip at one end. Both the sides of the points are extensively retouched.

Scrapers

Thirteen scrapers (8.6%) were studied. Most of the scrapers were end scrapers. Both small and large scrapers were studied. They were made on flakes. Almost all of the scraper heads display a regular retouch.

Debitage

While most microwear analyses have involved formal retouched tools (exceptions include Jensen 1986; Moss 1983; Odell 1980), ethnoarchaeological studies have numerous examples of the use of unretouched tools (Allchin 1957; Gould 1980; Hayden 1977; White and Thomas 1972). Since a large number of unretouched tools were found at the site during the Mesolithic period, samples of these tools were also studied for this dissertation research.

Twenty unretouched blades and 10 unretouched flakes were also studied for use-wear analysis. Unretouched blades have been found in large numbers during the phase. It is assumed that essentially these blades were the reserves or the preforms from which microlithic tools were produced when need arose.

Unretouched flakes studied vary in size from 8-24 cm. They are mostly the byproducts of the dressing of the core for blade preparation and they occur profusely during the both the Aceramic period indicating that the tools were made at the site.

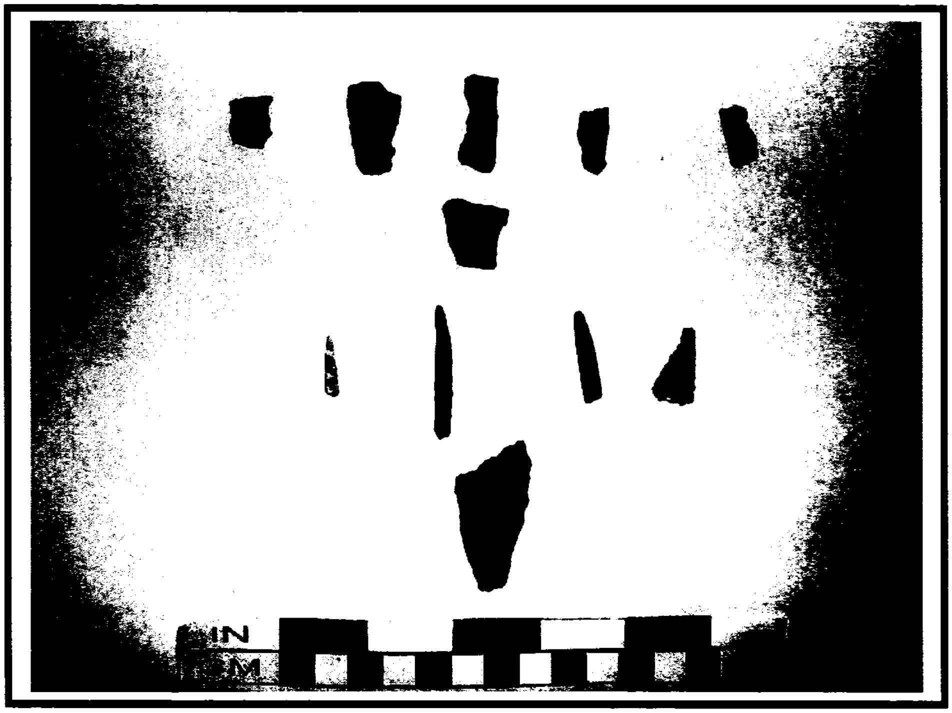

Figure 4.1: Sample of Microliths Studied from Aceramic Phase

Methods

In the present research, elements of both low and high power microscopy were used to determine the use-wear (See Chapter 2 for details on Methodology). The artifacts were cleaned in an ultrasonic cleaner with soap to remove the clay and dirt. Alcohol was used to remove finger grease during the analysis.

Results

Of the total of 150 tools studied from this phase, 81 (54%) [1] studied for use-wear from the Aceramic phase displayed use-wear traces, 49 (32.6 %) showed no traces, 10 (6.6%) were undetermined and 16 (6.6%) could not be studied due to post-depositional surface modification i.e., due to post-excavation damages, patination and weathering, etc. (Table 4.1 and Appendix C, See Figures 19-29). On 63 tools the contact material could be determined specifically (hide, bone, plant, etc.); while on 12 tools it possible to give merely the indication of (soft medium or hard contact material). Eight microliths exhibited microwear from multiple activities including plant cutting and hide scraping and cutting. Among the materials worked and processed were the following: meat/fish processing (9 specimens with the activities of skinning, butchering, cutting and scaling), hide (21 specimens, activities of scraping, piercing and drilling or boring), wood (7 specimens, activities of piercing and whittling), siliceous plant (9 specimens, activities of

[1] This is a pretty high percentage of tools with use evidence but it can be also related to the fact that mostly finished and retouched tools were studied for this research and very few unretouched tools were studied.

cutting) and roots and tubers (3 specimen activities included cutting and scraping). Twelve microliths (8 triangles and 4 points) showed evidence indicative of impact from being used as a projectile point. For some of the tools (n = 12), only the hardness of the material they were used on could be suggested (7 specimens, activities of longitudinal, transverse and carving hard and soft animal materials and 5 specimens, activities of longitudinal, transverse and carving hard and soft vegetal or plant material) (Table 4.2 and Appendix C).

Activities Inferred

On the basis of the use-wear studies, the following activities were inferred for the Aceramic settlers at Bagor and the data are presented in Table 4.3 and Appendix A).

Hide Working

The working of hide was, on the basis of the number of tools studied, the most frequent activity relating to stone tools at the site. Wear traces indicating hide work has been encountered on 21 tools (Table 4.4 and Appendix C). The microwear traces on 2 retouched and 1 unretouched blades were developed from scraping dry hide. Four scrapers were also used in scraping motion. Characteristic traces of hide wear include a moderate to severely rounded edge (more frequent on scraping tools than cutting or boring tools), a well defined band of rough polish (matte in texture) with cratered topography, the retouch is mostly scalar with hinged or feather terminations consistent with dry hide (Keleey 1980, Symens 1986; van Gijn 1990). In all these cases polish was

well distributed along the edge. Striations were visible frequently within the band of polish. The striations on the tools used for scraping were developed perpendicularly to the surface of the tools and extended far back into the tool.

Four retouched blades had greasy, bright polish indicating use on fresh hide or meat. Edge removal is present in 3 out of the 4 tools. The retouch was scalar with hinged termination and extensive edge rounding was also present.

Five points were used for reaming out holes in the hide. Here very bright and rough polish with greasy luster was formed. It was distributed along the edges of the tools and it was lightly developed over the whole surface of the point, becoming more intense near the edge and the tip of the point. Four points and one unretouched flake were used for as awls to drill hide. Well-developed polish and considerable rounding on the tips was found. On the retouched portion of the point the polish was most intense on the ridges between the flake scars.

Meat/Fish Processing

It must be kept in mind that both meat and fish processing have been the center of controversy among use-wear analysts (Appendix B). The use wear traces from meat and fish develop very slowly, can be invisible after only slight alterations of the flint surface and their development depends on a number of factors, such as raw material of the tool being used, the amount of time the tool was used, the variation in the butchering technique and the accumulation of fat on the working edges of the tools (Brose 1975; Scheurs 1992; van Gijn 1986; Vaughan 1985). Thus the number of artifacts in a prehistoric assemblage displaying wear attributed to meat or fish is therefore small and cannot be considered

representative of the original number of tools used for these kinds of activities. The experiments conducted for this research (Appendix B) also show that fish processing leads to polish very similar to that resulting from meat butchering. Therefore for this dissertation research meat and fish processing was studied as a category.

At Bagor nine microliths were used for meat/fish processing during the Aceramic phase. They included five retouched blades, one unretouched blade, one unretouched flake and two scrapers. Five tools have evidence of scalar edge scarring and edge removal is moderate with feather termination (Scheurs 1992; Symens 1986; van Gijn 1990). There is a band of rough and greasy polish, which is bright and reflective at some spots without any directionality and consistent with the bone polish (Appendix C). These tools were probably used to cut meat and came in contact with bones.

Four tools had bright, smooth polish (two with linear streaks of polish) in isolated spots with weakly developed luster and moderate edge rounding. These tools were probably used for hard fish-scale removal or butchering animals (Table 4.4 and Appendix C). It is important to note that linear streaks of polish are characteristic only of hard-scaled fish. For this reason, tools used for processing hard-scaled fish can be sometimes interpreted as meat butchering implements.

Wood Working

Seven microliths were used for wood working. The activities included whittling and piercing soft and hard wood (Table 4.4 and Appendix C). The degree of wear exhibited by woodworking varies from moderate to heavy work. Contact with wood

TABLE 4.1: ACERAMIC TOOL TYPES VERSUS RESULTS OF USE-WEAR ANALYSIS (Observation under Light Microscopy)

Tool Type	Analyzed	Not Interpretable (PDSM)	Number	Of	Artifacts
			Without Trace	Use Unsure	Used
Retouched Blades	53	2	13	6	33
Points	37	3	15	1	18
Triangles	17	1	8	0	8
Scrapers	13	2	1	1	7
Unretouched Blade	20	0	8	1	11
Unretouched Flake	10	2	2	1	4
Total	**150**	**10**	**49**	**10**	**81**

TABLE 4.2: ARTIFACT CATEGORIES VERSUS INFERRED MOTION IN ACERMIC PHASE (Observation under Light Microscopy)

	R. Blade	Point	Triangle	Scraper	U. Blade	U. Flake
Longitudinal	1	0	0	0	1	1
Transverse	5	0	0	0	1	0
Carving	0	0	0	0	0	0
Boring	0	0	0	0	0	0
Piercing	0	4	0	0	0	1
Drill	0	6	0	0	0	0
Puncture	0	4	0	0	0	0
Whittling	5	0	0	0	0	0
Cutting/Saw	6	0	0	1	1	1
Butchering	5	0	0	2	1	1
Impact Damage	0	4	8	0	0	0
Scraping	9	0	0	4	1	0
Multipurpose	2	0	0	0	6	0
Unsure	6	1	0	1	1	1
Total	**39**	**19**	**8**	**8**	**11**	**5**

R. Blade = Retouched Blade, U. Blade = Unretouched Blade, U. Flake = Unretouched Flake

TABLE 4.3: SUMMARY OF THE USE-WEAR TRACES IN MICROLITHS FROM THE ACERAMIC PHASE (Observation under Light Microscopy)

	Hide			Plant		Wood		Meat/ Fish			
Type	Scrape	Pierce Or, Puncture	Drill	Cut	Scrape	Whittle	Pierce Or, Drill	Butcher	MT	IT	S/H (Material)
R. Blade	6	0	0	6	3	5	0	5	2	0	6
Triangle	0	0	0	0	0	0	0	0	0	8	0
Point	0	4	5	0	0	0	2	0	0	4	3
Scraper	4	0	0	1	1	0	0	2	0	0	0
U. Blade	1	0	0	1	0	0	0	1	6	0	2
U. Flake	0	1	0	0	0	0	0	1	0	0	1
Total	**11**	**5**	**5**	**8**	**4**	**5**	**2**	**9**	**8**	**12**	**12**

R. Blade = Retouched Blade, U. Blade = Unretouched Blade, U. Flake = Unretouched Flake, MT = Multipurpose, IT = Impact Damage From Projectile, UND = Undetermined PDSM = Post Depositional Surface Modification, S/H Material = Soft Hard Material

caused a smooth and bright polish with domed topography. The retouch formed from the contact of wood is deep and well defined (van Gijn 1990). The retouch on tools (5 blades) used for whittling are scalar and half-moon shaped. The edges display slight rounding. On all the tools there is evidence of extensive edge removal and edge damage with snap termination.

Two points were used for woodworking. The tip of the point shows bright polish on the small shallow scars formed at the tip of the point and no striations. Studies have shown that drilling wood in a rotary motion causes such damage (Keeley 1980: 42).

Siliceous Plant and Roots and Tubers Working

Fourteen microliths were used for cutting siliceous and non-siliceous plants during the Aceramic phase (Table 4.4 and Appendix C). Three microliths, including 1 retouched blades, 1 unretouched blades and 1 scraper – were used for cutting and scraping roots and tubers. These activities produce polish that develop very slowly but are very distinctive. The polish is rough, long and deep striations are present. The most important character of the roots and tubers was the lack of directionality (Appendix C).

Cutting of siliceous plants such as reeds, wild grass and cereals (8 retouched blades and 1 unretouched flake) produces highly reflective polish with well-developed retouches and slight edge rounding (Table 4.4 and Appendix C).

Use as Projectiles

Impact fractures were encountered on eight triangles and four points. The tip of the triangles displayed evidence of parallel-sided fractures and various degrees of

crushing. The tips of the points were damaged. Linear polish and striations were visible on all the tools running parallel to the impact. Linear polishes are plastic changes in the surface of the raw material and, in a light microscope, appear as long-shining stripes on the surface. Striations are small scratches on the surface (Fisher *et al.* 1984; van Gijn 1990) (Appendix C).

Hard and Soft Material Working

On 12 tools only the hardness of the material was determined. Seven tools were used on soft and hard plant material (Table 4.4). Five microliths were used on animal material.

To determine the function of these tools they were further studied under SEM[2] to observe the changes in their surface texture and micro-topography, which is not discernible under a light microscope. SEM studies reveals that the five tools used on soft animals were used for scraping hide (Appendix C). Under 1500 X magnification the tools show a very well developed knobbly surface on the outermost edge. In the direction of the work shallow linear features are visible. This area consists of small caps with well-defined circumference (Knuttson 1988). SEM also revealed that the three points labeled as used on hard plant material were used for drilling wood (Appendix C). Drilling wood makes very distinct changes in the micro-topography. Surface cracks and linear feature striations were observed on the tip of the point used for drilling wood. Striations are surrounded by few impact pits (Knuttson 1988).

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[2] It must be kept in mind that both SEM and EDS are very expensive and time consuming so only a very limited number of tools were studied under SEM and EDS

TABLE 4.4: TOOL TYPE VERSUS WORKED MATERIAL IN THE ACERAMIC PHASE

	R. Blade	Point	Triangle	Scraper	U. Blade	U. Flake
Meat/ Fish Butchering	5	0	0	2	1	1
Soft Vegetal material	1	0	0	0	1	0
Medium Vegetal material	0	0	0	0	1	1
Hard Vegetal material	0	3	0	0	0	0
Roots and Tubers	1	0	0	1	1	0
Hard Animal	0	0	0	0	0	0
Soft Animal	5	0	0	0	0	0
Siliceous Plant Work	8	0	0	0	0	1
Wet Hide	4	0	0	0	0	0
Dry Hide	2	9	0	4	1	1
Hard Wood	4	2	0	0	0	0
Soft Wood	1	0	0	0	0	0
Animal Shooting	0	4	8	0	0	0
Multipurpose	2	0	0	0	6	0
Total	**33**	**18**	**8**	**7**	**11**	**4**

R. Blade = Retouched Blade, U. Blade = Unretouched Blade, U. Flake = Unretouched Flake

Multipurpose Tools

Eight microliths (2 retouched blades and six unretouched blades) were used as multipurpose tools. They have traces of use from cutting siliceous plants, scraping hide and cutting bone.

Tool Techno-Morphology and Tool Use during the Aceramic Phase

As noted above, one of the goals this study was to examine the relationship between tool techno-morphology and tool use (See Chapter 6 for details). Four types of retouched tools (blades, points, triangles and scapers) and a few unretouched blades and flakes were examined for this study. Table 4.5 shows their hypothesized function on the basis of techno-morphology and their use by the hunter-gatherers at Bagor. The results are mixed concerning the relationship between techno-morphological types and their use. A blade's function (n= 53), for example, is that of a knife for butchering animals, cutting plants etc. Although blades were used as knives for cutting and longitudinal (n=13) activities by the Mesolithic people at Bagor, a few of them were also used as scrapers for scraping and transverse activities like whittling (n = 16), and some were used for multi-purposes such as both scraping and cutting (n= 2).

Points (n=37) and triangles (n=17) are presumed by the excavators to be used as barbs in arrows to hunt animals. Although all the used triangles (n= 8) have

TABLE 4.5: TOOL TECHNO-MORPHOLOGY VERSUS TOOL USE DURING THE ACERAMIC PHASE

Tool Type	Hypothesized Function	Results of Analysis of Use
A. Blade	Knives	Multipurpose – Both as Knife and as Scrapers
B. Triangle	Projectile point	Projectile Point
C. Points	Projectile point	Both as Awls or Drills and also as Projectiles
D. Scraper	Scraping	Scraping and Cutting
E. Unretouched Blades And Flakes	Multipurpose	Multipurpose

impact traces resembling a projectile, the points have impact damage both from being used as projectiles (n= 4) and others (n= 14) were used for different activities like piercing, drilling and puncturing hide and wood.

The scrapers (n = 13) were put to use for scraping (n= 3), and cutting and butchering (n = 3). For the unretouched tools it is proposed that they are usually used on a need basis. At Bagor this has proved to be true. The microliths studied show that they are used for a wide range of purposes. Thus we see the relationship between form and function does not hold well in all the cases at Bagor.

Use-wear analysis of Ceramic Phase Microliths

One hundred and fifty microliths made from chert provided by the excavator (Vasant Shinde from 2001-2002 excavation seasons) were studied from the Ceramic Phase of the Mesolithic period (Tables 3.5-3.6, Figure 4.2 and Appendix D). This allows us to determine the changes in the use and utility of the tools with the change to food production. The study sample included the following types:

Retouched Blades

Sixty-five blade tools (43.3% of total 150) were studied. Long, parallel-sided blades are most common in the Ceramic phase (Shinde: Personal Communication). Generally they display a regular retouch, located on the lateral edges and extending either over the entire length or along portions of it.

Crescents

Twenty-nine crescents (19.3 %) were studied. They are half, moon-shaped geometric tools.

Triangles

Five triangles were studied from the Ceramic phase. Of these 2 were isosceles and 3 were scalene triangles.

Points

Ten points were studied from the Ceramic phase. Generally they display retouch over the entire length of the tool. Seven of these tools have very rounded tips and 3 have an acute angled tip.

Scrapers

Two scrapers made on flakes were studied. Most of these are end scrapers, although 2-sided scrapers were also studied.

Retouched Flakes

Eleven retouched flakes were studied from the Ceramic phase. All of them display retouch on the lateral edge of the tools.

Figure 4.2: A Sample of Microliths Studied from Ceramic Phase

Debitage

Eighteen unretouched blades and 10 unretouched flakes were studied for this study.

Results

Of the total 150 tools studied from this phase, 82[3] (53.3%) displayed use-wear traces, 49 (32.6 %) showed no traces, 5 (3.3%) could not be determined, 13 (6.6%) could not be studied due to post-depositional surface modification like post-excavation damages, patination and weathering etc. (Table 4.6, and Appendix D). On 73 tools the contact material could be determined exactly (hide, bone, plant and soil, etc.); on 7 it was merely possible to give the indication of soft medium or hard contact material and 2 were multipurpose like plant cutting and wood whittling. Amongst the materials worked and processed were meat/fish processing (9 specimens, activities of skinning, butchering, cutting and scaling), hide (15 specimens, activities of scraping, piercing and drilling or boring), wood (14 specimen, activities of cutting and whittling), siliceous plant (20 specimen, activities included cutting) and roots and tubers (10 specimen activities of cutting) and 2 had use-wear from inorganic material (soil). Five microliths (4 triangles and 1 point), showed evidence indicative of impact, of being used as a projectile point. For some of the specimens (n = 7), it was evident that were used. While hardness of the

[3] This is a pretty high percentage of tools with use evidence but it can be also related to the fact that mostly finished and retouched tools were studied for this research and very few unretouched tools were studied,

material could be suggested, the exact material and activity performed could not be determined. For results see Table 4.7 and Appendix D.

Activities Inferred

On the basis of the use-wear studies the following activities were inferred for the Ceramic settlers at Bagor (Table 4.8, Appendix D, See Figures 30-33).

Hide Working

Hide working was a very common activity during the Ceramic phase also. Fifteen tools (20.5 % of the total number with use-wear traces) were used for hide working activities. Characteristic wear attributes include heavily rounded edges (Table 4.9), band of rough polish and no edge removals. Thirteen tools had the "matt" polish resulting from dry hide working, and 2 tools had "greasy wet" appearance attributed to use on wet hide. Motions inferred included scraping (7 tools), cutting (3 tools) and piercing (5 tools).

Meat/Fish Processing

Nine tools (13.1%) show evidence for contact with meat and fish processing (Table 4.9 and Appendix D). At least one of the tools has traces from scraping hard fish scales. The polish is bright, smooth and matte and with clear directionality as seen in experiments used to butcher meat and cut fish with bones. As mentioned above, it is quite possible that a larger number of tools was used for meat/fish processing but the traces are lacking because traces of use on meat and fish (with small bone) are extremely

slow to develop and depend on several factors such as the amount of time the tool was used, the raw material of the tool, etc. so archaeologically meat and fish traces are not very representative.

Wood Work

Another important activity during the Ceramic period was woodworking. Of the total used tools 14 or 17.5% were used on wood. The polish present is domed and smooth, and the edges are slightly to moderately rounded. The tools were used for whittling, cutting and piercing wood (Table 4.9, and Appendix D). The points used for piercing wood had very well developed deep and scalar retouches. The experiments have shown that rotary motions produce such use-wear.

Plant Work

The most important activity during the Ceramic period was plant working. Thirty tools (37.5% of the tools) were used for various activities such as reaping cereals and reeds and cutting soft plants. Twenty were used for reaping cereals and ten for cutting soft grass, reeds and roots and tubers (Table 4.9 and Appendix D).

Use-wear from cutting/reaping cereals are present in 11 crescents and 7 retouched blades. The polish is smooth and bright and highly reflective; in most cases it has very deep striaes. Some tools (n=9) that have polishes are rougher and flatter and are scarred with numerous striations. They might have come in contact with reeds or soil particles while reaping. Two tools were used for cutting dry reed. One of the tools has a bright

TABLE 4.6: CERAMIC TOOL TYPES VERSUS RESULTS OF USE-WEAR ANALYSIS (Observation under Light Microscopy)

Tool Type	Analyzed	Not Interpretable OR, PDSM	Number	Of	Artifacts
			Without Trace	**Use Unsure**	**Used**
Retouched Blades	65	7	23	3	32
Crescents/ Lunates	29	3	12	0	14
Points	10	0	0	0	10
Triangles	5	0	1	0	4
Scrapers	2	0	0	0	2
Retouched Flake	11	1	1	0	9
Debitage (Unretouched Blades)	18	1	10	0	7
Debitage (Unretouched Flakes)	10	0	2	2	6
Total	**150**	**13**	**49**	**5**	**83**

TABLE 4.7: ARTIFACT CATEGORIES VERSUS INFERRED MOTIONS IN THE CERAMIC PHASE (Observation under Light Microscopy)

	R. Blade	Crescent	Point	Triangle	Scraper	R. Flake	U. Blade	U. Flake
Longitudinal	1	0	0	0	0	1	0	0
Transverse	1	0	0	0	0	1	0	0
Carving	0	0	0	0	0	0	0	0
Piercing	0	0	8	0	0	0	0	2
Whittling	7	0	0	0	0	1	3	1
Cutting/Harvesting	14	14	0	0	0	1	0	0
Butchering	2	0	0	0	0	3	2	2
Scraping	4	0	0	0	2	2	1	1
Multipurpose	1	0	0	0	0	0	1	0
Shooting	0	0	1	4	0	0	0	0
Unsure	3	0	0	0	0	0	0	2
Others	2	0	0	0	0	0	0	0
Total	**35**	**14**	**9**	**4**	**2**	**9**	**7**	**8**

R. Blade = Retouched Blade, R. Flake = Retouched Flake, U. Blade = Unretouched Blade
U. Flake = Unretouched Flake

TABLE 4.8: SUMMARY OF ACTIVITIES DURING THE CERAMIC PHASE (Observation under Light Microscopy)

	Hide			Plant		Wood			Meat/Fish			
Type	Scrape And Cut	Pierce Or, Puncture	Drill	Cut Or, Harvest	Scrape	Whittle	Pierce Or, Drill	Cut	Butcher	MT	IT	S/H
R. Blade	4	0	0	12	2	7	0	0	2	2	0	2
Triangle	0	0	0	0	0	0	0	0	0	0	4	0
Point	0	6	0	0	0	0	1	0	0	0	1	2
Scraper	2	0	0	0	0	0	0	0	0	0	0	0
U. Blade	0	0	0	0	1	3	0	0	2	1	0	0
U. Flake	1	0	0	0	0	1	1	0	2	0	0	1
R. Flake	2	0	0	0	1	1	0	0	3	0	0	2
Crescent	0	0	0	14	0	0	0	0	0	0	0	0
Total	**9**	**6**	**0**	**26**	**4**	**12**	**2**	**0**	**9**	**3**	**5**	**7**

R. Blade = Retouched Blade, U. Blade = Unretouched Blade, U. Flake = Unretouched Flake and R. Flake = Retouched Flake, MT = Multipurpose, IT = Impact Damage From Projectile, UND = Undetermined, PDSM = Post Depositional Surface Modification, S/H Material = Soft Hard Material

metallic polish consistent with the experimental tool used for cutting dry reed (Appendix B and D).

Three microlithic (3 crescents) blades exhibited signs of cutting soft grass. Very little micro-scarring is present on these tools; the polish is bright and smooth, extending to around 1/2 cm of the tools. The experiments on cutting 'munj' grasses used for making ropes in the present village of Bagor showed very similar traces to the soft plant traces found in the archaeological sample. Seven are consistent with the use developing from scraping dirty and gritty roots and tubers.

Hard and Soft Material Working

On some tools (7 or 8.53%) it was possible, on the basis of polish distribution and the nature of edge-removals, to distinguish whether the tools were used on hard or soft material[4]. It was not possible to determine the exact material used (Table 14). Motions inferred encompassed transverse, longitudinal and unsure.

Use as Projectiles

Five (6.3%) microliths were used as projectiles. They have displayed damage in the form of impact fracture on their tip (Appendix B and Appendix D). The tools have also shown linear polish parallel to the impact damage that is common in the tools used as projectiles for shooting animals.

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[4] Since these tools were studied in India SEM and EDS analysis could not be done to determine their exact use.

TABLE 4.9: TOOL TYPE VERSUS WORKED MATERIAL IN THE CERAMIC PHASE (Observation under Light Microscopy)

	R. Blade	Point	Triangle	Scraper	U. Blade	R. Flake	Crescent	U. Flake
Meat/ Fish Butcher	2	0	0	0	2	3	0	2
Soft Wood	0	0	0	0	0	0	0	0
Hard Wood	7	1	0	0	3	1	0	2
Siliceous Plant	7	0	0	0	0	0	11	0
Roots and Tubers	5	0	0	0	1	1	3	0
Cutting Reed	2	0	0	0	0	0	0	0
Dry Hide	2	6	0	2	0	2	0	1
Wet Hide	2	0	0	0	0	0	0	0
Animal shooting	0	1	4	0	0	0	0	0
Hard Vegetal	0	1	0	0	0	0	0	0
Soft Vegetal	1	0	0	0	0	0	0	0
Soft Animal	1	0	0	0	0	1	0	1
Hard Animal	0	1	0	0	0	1	0	0
Multipurpose	2				1			
Total	**33**	**10**	**4**	**2**	**7**	**9**	**14**	**6**

Tool Techno-Morphology and Tool Use during the Ceramic Phase

As noted above, one of the goals this study was also to examine the relationship between tool techno-morphology and tool use (For Details See Chapter 6). Six types of microliths were examined for the Ceramic phase. Table 4.10 shows their hypothesized function on the basis of techno-morphology and their use by the farmers at Bagor. The results are interesting concerning the relationship between techno-morphological types and use. A retouched blade's function, for example, is that of a knife for butchering animals, cutting plants and etc. It is evident from Table 4.9 that more retouched blades (24 of the 31 retouched blades used for cutting plants and wood) were being used for cutting purposes than scraping activities in the Ceramic phase. Points and triangles assumed by the excavators to have been used as barbs in arrows to hunt animals. All the used triangles have impact traces resembling a projectile. The points have impact damage both from being used as projectiles and being used for different activities – like piercing, drilling and puncturing hide and wood. Neither of the excavators has proposed a particular function for crescents at the site. Use-wear analysis of the crescents show that they were used for cutting and harvesting plants only at the site.

TABLE 4.10: TOOL TECHNO-MORPHOLOGY VERSUS TOOL USE DURING THE CERAMIC PHASE

Tool Type	Hypothesized Function	Results of Analysis of Use
A. Blade	Knives	Multipurpose – Both as Knife and as Scrapers
B. Triangle	Projectile point	Projectile Point
C. Points	Projectile point	Both as Awls or Drills and also as Projectiles
D. Scraper	Scraping	Scraping
E. Unretouched Blades And Flakes	Multipurpose	Multi purpose
F. Crescents	-	Harvest Plants

Discussion

Microwear analysis of microlithic tools from the Mesolithic period at Bagor has given us very important insights into the activities of the Aceramic and Ceramic prehistoric settlers at the site (For details see Chapter 6, and Figure 6.1). The analysis reveals the various activities such as hide working (25% of used tools), meat and fish processing (12 % of used tools), woodworking (9 % of used tools) and plant cutting (15 % of used tools) were carried out at the site during the Aceramic phase. During the Ceramic Mesolithic Phase at Bagor the prehistoric people participated in activities such as hide work (20% of used tools), meat and fish processing (9% of used tools), wood work (17% of used tools) and plant cutting (36% of used tools) carried out at the site.

Hide working is a prominent activity at the site. A variety of microliths were used for hide working activities at the site during the Aceramic and Ceramic phases including retouched blades, points, scrapers, unretouched flakes and blades were also used (Tables 4.3 and 4.8). Given the character of the wear traces, indicative of use on both 'wet and dry hide,' it can be argued that initial process of cleaning hide and then processing it was carried out by Mesolithic settlers.

A variety of plant working activities were also carried on at the site. The toolkits employed during the Aceramic phase for plant activities include retouched blades, scrapers, unretouched flakes and blades (Table 4.3). During the Ceramic phase retouched blades and crescents were being specifically used for plant working activities (Table 4.8). Use-wear analysis of the Aceramic and Ceramic phase artifacts shows that siliceous wild plants, cereals and reeds were used by the prehistoric settlers at the site. Reeds and

grasses were probably used as building material or other craft activities such as making ropes. Of the tools used for plant activities, some (3% during the Aceramic phase and 4.87% during the Ceramic period) were used on roots and tubers. Although the numbers are extremely low, they are nonetheless important. Experimental research (Sievert 1992) has shown that processing of roots and tubers produces use-wear that are not very characteristic and are very slow to develop, so if the tools are not used for a long time the evidence of wear can be lacking. This implies that wear analysis provides a marginally useful way to identify tuber processing in archaeological records. However it also suggests that if root and tuber processing implements are present in an archaeological assemblage it presents a good case for intensive use of tools and it might be a good indicator that root crops were either intensively used or even cultivated at the site (Sievert 1992). The presence of root and tuber processing implements at Bagor suggests that it roots and tubers were an important part of the prehistoric diet.

Only 12% of the tools during the Aceramic phase and 9% during the Ceramic phase have meat/fish processing polishes on them. The numbers sound really insignificant since the Aceramic people subsisted largely on hunting of wild animals for their subsistence. Microscopic analysis of the experimentally produced and utilized flakes (Brose 1975) for butchering activities suggests that lithology, the amount of time the flake was used, the variation in the butchering technique and the accumulation of fat on the working edges are major factors in the creation of the striations and polishes on stone tools. These factors should be taken into consideration while trying to distinguish activity areas of prehistoric sites, which represent specific butchering activities. Experimental studies have also shown that it is possible to butcher an animal without

touching a bone (Patterson 1981). Thus it is possible that much higher numbers of artifacts (especially ones determined as being used on soft animal material) were used for cutting meat, but traces are lacking and not evident in the archaeological assemblage.

The presence of woodworking tools is important. It is likely that wood was not only used for hafting the microliths but also provided building material for the simple shelter structures used by both the hunter-gatherers and the farmers at the site.

The presence of very few projectiles (only 15% of total used tools during the Aceramic and 6% during the Ceramic phase) should also be interpreted with caution. As Gijn (1990) suggests there are several taphonomic processes that have to be kept in mind while reconstructing the activities at the site. It must be kept in mind that some tools such as projectiles used for hunting of animals, and crescents and sickles used for harvesting plants – might have been carried around and discarded at the site of use and archaeological data might be biased by the tools which were brought back for retooling, repair and hafting activities. Also, bone points may have been used for projectiles (Vasant Shinde: Personal Communication).

Conclusion

The use-wear analysis of the tools from Bagor has given us important insights into the activities of the hunter-gatherers and farmers at the site. A very high frequency of tools studied from Bagor (54% of the tools studied from the Aceramic Phase and 53.3% of the tools studied from the Ceramic Phase) was utilized. Although it can be related to the fact that proportionately fewer unretouched tools were studied for this

research. Nonetheless this is very significant. It suggests that the tools were very well curated at Bagor. Also, that the sites were occupied for a fairly long time or that the activities carried out the sites were fairly intense (R. Yerkes: Personal Communication).

The evidence for hide work, meat and fish processing and wood-working continued from the Aceramic period to the Ceramic period. There is an increase in the activities involving cutting of plants from 15% to 36%. Even though use-wear analysis has shows that different kinds of plant materials were being processed by the prehistoric settlers at the site, it failed to provide information about the specific kinds of plants being used by the hunter-gatherers and food producers at the site. To reconstruct the plant food processed at the site required combining and complementing plant residue-analysis like starch-grain analysis with use-wear research. The details of the starch-grain studies will be discussed in the next chapter.

Although due to constraints of money and time SEM was used for studying very limited tools from Bagor. Nonetheless this research shows the relative importance of analytical methods such as SEM. SEM was used to determine the use wear eight microliths (including 5 retouched blades and 3 points) the specific use of which could not be determined by light microscope. SEM studies helped to determine that the five retouched blades used on soft animals were used for scraping hide and the three points used on hard plant materials were used for drilling wood. This is an important contribution as it shows that used together with light microscope, SEM can be prove to be a very powerful methodology for understanding the primary economic activities of the prehistoric people.

CHAPTER 5

SUBSISTENCE AT BAGOR:

RESULTS OF STARCH-GRAIN ANALYSIS

Background

The origin of agriculture in South Asia has been obscure. Perennial questions unanswered in the archaeology of South Asia are whether agricultural and pastoral origins were single or multi-centered phenomena and whether the spread of subsistence practices based on domestic taxa over vast areas reflects indigenous adoptions, colonization or both (Meadow 1996)? This lack of understanding is due to the fact that, despite the existence of clear evidence for a number of crop origins in South Asia, most notably tropical pulses as well as several localized millets, tree cotton and possibly sesame, there has been very little problem-oriented research into the processes by which these plants were brought into cultivation (Fuller 2002, 2004 – Also See Table 5.1). Some authors have maintained that the native taxa may have been domesticated before the introduction of crops from other region (Fuller 2002; Mehra 1997; Vishnu-Mitte 1989). But it is usually suggested that the local crops were domesticated only after cultivation was established based on introduced domesticates (Hutchinson 1976; Harlan 1992; Wilcox 1992; Shinde 2002).

TABLE 5.1: CROPS OF PROBABLE SOUTH ASIAN ORIGIN (AFTER Fuller 2002, Table 8, pp. 293 – 294)

Crop	**Common Name**	**Frequent synonyms**	**Region of Origin (Ref.)**	**Early finds, region of origin**	**Other Early finds, South Asia**
Paspalum scrobiculatum L.	Kodo Millet	-----	Peninsular India (De Wet *et al.* 1983; M' Ribu and Hilu 1996)	See next column	Senuwar I B, Bihar, 1800 – 1200 B.C. (Saraswat and Chanchala 1995); Rojdi C, Gujarat, 2000 – 1700 B.C. (Weber 1991); Daimabad, 1500 – 1000 B. C. (Vishnu-Mittre *et al.* 1986); Narhan c. 1200 B.C. (Saraswat *et. al* 1994)
Panicum sumatrense Roth.	Little Millet	*Panicum miliare* nom illeg.	Peninsular India (?) (De Wet *et al.* 1983; Hiremath *et al.* 1990; M' Ribu and Hilu 1996	Southern Neolithic sites 3rd M. B. C. (?) (Fuller *et al.* 2004)	Harappan Rojdi from *c.* 2500 B.C. (Weber 1991), Babar Kot, Oriyo Timbo, Gujarat; 2000-1700 (Reddy 1994); Balatha by 2000 B.C. (Kajale 1996), Inamgaon 1200 – 900 B.C. (Kajale 1988)
Echinochloa colona (L.) Link. ssp. *frumentacea*	Sawa millet	*E. frumentacea (Roxb)*	Peninsular India multiple domesticati-on (De Wet *et al.* 1983; Hilu 1994	Southern Neolithic sites 3rd M. B. C. (?) (Fuller *et al.* 2004)	Narhan (?), c. 1200 B.C. (Saraswat *et al.* 1994)

TABLE 5.1 (CONTD.): CROPS OF PROBABLE SOUTH ASIAN ORIGIN (AFTER Fuller 2002, Table 8, pp. 293 – 294)

Crop	**Common Name**	**Frequent synonyms**	**Region of Origin (Ref.)**	**Early finds, region of origin**	**Other Early finds, South Asia**
Setaria pumila (Poir.) Roem. and Achult	Yellow Foxtail Millet	*Setaria glauca nom illeg.*	Cult. and Domes., India only (De Wet *et al.* 1979; De Wet 1995)	Caryopisi not yet clearly distinguished from other *Setaria* species. Study in progress	*S. pumila/S. verticillata* present on Southern Neolithic sites from mid. 3rd M. B.C. (Fuller *et al.* 2004). Numerous sites with early find of *Setaria* (dating the 2500 – 1800 B. C., could be S. *pumila*, including Balathal, Senuwar IA, Sanghol, Babar Kot, Surjotada)
Brachiaria ramose (L.) Stapf.	Brown Top Millet	*Urochloa ramosa* (L.) Nguyen	Cult. and Domes., India only (De Wet 1995)	none	none
Vigna mungo (L.) Hepper	Urid, Black Gram	*Phaeseolus mungo* L., not *V. angularis* (Wild.) Ohwi and Ohashi	South Asia? Himalayan Foot hills (Lawn 1995)	See next column	Rojdi A (Weber 1991), Balathal (Kajale 1996), Burthana (?) and Mitathal (?) Wilcox 1992), 2500 – 2200 B.C.; Koldihwa; after 2000: Maharashtra sites

TABLE 5.1 (CONTD.): CROPS OF PROBABLE SOUTH ASIAN ORIGIN (AFTER Fuller 2002, Table 8, pp. 293 – 294)

Crop	**Common Name**	**Frequent synonyms**	**Region of Origin (Ref.)**	**Early finds, region of origin**	**Other Early finds, South Asia**
Vigna radiata (L.) Wilczek	Green Gram, Mung Beans	*Phaeseolus radiatus* L., P. aureus Roxb.	South Asia: Western Ghats (?) (Lawn 1995)	Southern Neolithic sites 3rd M. B. C. (?) (Fuller *et al.* 2004)	Rojdi C, 2000-1700 B. C. (Weber 1991), Balathal, by 2000 B.C. (Kajale 1996); after 2000 B.C.: Chalcolithic Maharashtra
Vigna acontifolia (Jacq.) Marechal	Golden Gram/ Moth Beans	---------	South Asia: (?) (Lawn 1995)	See next column	Narhan, 1000-800 B.C. (Saraswat *et al.* 1994)
Cajanus Cajun (L.) Millsp.	Pigeon Pea, Tuvar	---------	India: S. Orissa, Bastar, from C.cjanifolia (Haines) , van der Maeson (1986; 1995)	Closest finds in the next column	Peddamudiyam, 1300-1700 B. C.; T. Garhi c. 1500 B.C.; Sanganakallu, Karnataka, mid 2nd M. B.C.? (Fuller *et al.* 2004)
Macrotyloma uniflorum (Lam.) Vercourt	Horse Gram	*Dolichos biflorus* nom, *Illeg.*, *D. uniflorus* Lam.	South Asia: (Verdocurt 1970; Smartt 1985)	See next column	Harappa Burthana and Mitithal (Wilcox 1992); Kunjhun *c.* 2500 B. C.; Rojdi C, 2000-1700 B.C. (Weber 1991); Chalcolithic Maharashtra sites; Southern Neolithic sites, 3rd M. B.C. (?) (Fuller *et al.* 2004)

TABLE 5.1 (CONTD.): CROPS OF PROBABLE SOUTH ASIAN ORIGIN (AFTER Fuller 2002, Table 8, pp. 293 – 294)

Crop	**Common Name**	**Frequent synonyms**	**Region of Origin (Ref.)**	**Early finds, region of origin**	**Other Early finds, South Asia**
Sesamum indicum L.	Sesame, Til	---------	South Asia? Pakistan (Bedigian and Harlan 1986)	Harappan Makran (Tenberg 1998); Harappa (*c.* 2500-2000 B. C.)	See previous column. Also Sanghol, Punjab, 1900 – 1400 B.C. (Saraswat and) Chanchala 1997); Senuwar ii, 1200–600 (Saraswat *et al.* 1994); Narhan, from *c.* 1200 B. C. (Saraswat *et al.* 1994)
Gossypium arboretum L.	Tree Cotton		South Asia: Guajrat/Sindh? (Santhanam and Hutchinson 1974)	Mehrgarh Baluchistan? 5000 B. C.	See prev (?); Mohenjodaro, mature Harappan (cloth) 2500-2000 B.C. (Gulati and Turner 1929; Marshall 1931: 33); Hullas (seed), Late Harappan 1800-1300 B. C. (Saraswat 1993); Nevasa (thread) 1500-1200 B.C. (Gulatit 1961). (See Janaway and Coningham 1995)

The problem is made more complicated by the fact that the identification of plant resources has been problematic in the Indian archaeological context for various reasons: (1) their direct evidence in the form of intact macroscopic remains is rare due to the preservation conditions; (2) there is a lack of use of systematic techniques such as floatation and screening during the excavations to ensure complete and uniform recovery of such remains (Mehra 1999); (3) plant residue studies like phytolith analysis are still in its infancy (Kajale and Mulholland 1995), and the potentials of others, such as starch-grain analysis, have not yet been explored by Indian archaeobotanists.

Indirect evidence for the utilization of plant resources has come from analyzing the formal shape of stone artifacts, some of which have been grouped within distinct functional classes (e.g., blades, axes, grinding stones, rubber stones, and pounding stones, etc.). Functional classifications of this kind have been supported by preliminary use-wear studies (Pant 1979; Kashyap *et al.* 2006), but no attempt has been made to systematically study distinctive plant residues (e.g., starch-grain analyses or phytoliths) on stone tools to determine the specific plant food utilized by the prehistoric settlers.

For this dissertation research, use-wear analysis was conducted and 300 microliths studied from the Mesolithic site of Bagor to determine the economic and subsistence activities of the prehistoric settlers. The studies show an increase in the activities involving use of plants from 15% in the Aceramic phase to 36% in the Ceramic phase. However, though use-wear analysis show that different kinds of plant materials were being processed by the prehistoric settlers at the site, it failed to provide information about the specific kinds of plants being used by the hunter-gatherers and food producers at the site. To reconstruct the plant food processed at the site required combining and

complementing plant residue analysis (such as starch-grain analysis) with use-wear research. For the present research first a reference collection was prepared (Appendix E and Appendix). Starch-grain analysis was performed on 20 archaeological samples (including 15 microlithic tools such as blade and crescents, 2 grinding stones and 3 soil samples) from the Mesolithic period at Bagor (Table 5.2). As mentioned before starch-grain analysis was conducted at the Smithsonian Institute, Museum Support Center (See Chapter 2 for details on methodology) under the supervision of Drs. Dolores Piperno and Linda Perry.

Extraction of Starch-Grains from Modern Plants

To the best of my knowledge, there is neither a comparative collection nor literature on starch components of major economic plants in India. One of the goals of this research was to prepare a reference collection. This included the starchy plant foods utilized in Rajasthan (Saxena 1979) (See Appendix E).

The preparation of a modern reference collection was carried out as follows. Fresh plant materials such as seeds, fruits and vegetables were soaked in water over night. The seed coats and other non-starchy structures were then removed. The starch bearing structures (cotyledons and endosperms) were pounded in a small amount of water to make a smooth paste and then were allowed to dry. After drying they were ground into a fine powder (Pearsall 2000; Piperno and Holst 1998; Piperno *et al.* 2000, 2004).

TABLE 5.2: MORPHOLOGICAL SIZE AND SHAPE OF STARCH-GRAINS IN MODERN PLANTS STUDIED COMPARED WITH THE ARCHAEOLOGICAL GRAINS

Modern Plants	Size Range (µm)	Morphological Shape of Grain
Cyperus rotundus L.	13.42–62.78	Simple
Phoenix dactylifera (L.) Roxb	3.37–26.45	Simple
Sesamum indicum	5.06–14.88	Compound
Vigna mungo	8.41–32.31	Simple
Vigna radiata	7.86–34.34	Simple
Vigna radiata sublobata	6.44–31.23	Simple
Lens culinaris	10.30–37.70	Simple
Macrotyloma uniflorum	12.57–52.51	Simple
Lablab purpureus	11.72–34.30	Simple
Vigna aconitifolia	12.30–44.40	Simple
Cajanus cajan L.	19.11–48.52	Simple
Hordeum vulgare	18.00–26.00	Simple
Sorghum bicolor L.	8.68– 30.52	Simple
Pennisetum glaucum	7.66– 15.20	Simple
Eleusine coracan L.	-	Compound
Oryza sativa	3.72– 9.97	Compound
Triticum aestivum	8.00–30.00	Simple
Ipomoea batatas	7.80–37.85	Compound
Zingiber officinale Rosc	13.12 – 39.89	Simple

TABLE 5.2: MORPHOLOGICAL SIZE AND SHAPE OF STARCH-GRAINS IN MODERN PLANTS STUDIED COMPARED WITH THE ARCHAEOLOGICAL GRAINS (CONTD.)

Modern Plants	Size Range (µm)	Morphological Shape of Grain
Kaempferia galang	14.33 – 26.45	Simple
Curcuma longa	18.31 – 50.67	Simple
Tamarindus indica L.	2.15 – 26. 67	Simple
Amorphophallus campanulatus	5.39 – 26.89	Compound
Colocassia esculenta	1.91 – 5.450	Compound
Mangifera	6.26 – 24.25	Simple
Solanum	8.62 – 42.43	Simple
Nymphaea lotus L.	3.00 – 7.90	Compound

Archaeological Grains	Tool and Soil Sample no.	Size Range (µm)	Morphological Shape
cf. Solanum (Egg plant)	1, 5, 8, 13, 14, 16, 24, 25	15.91–41.51 (pericarp) 1.73–32.50 (seed)	Simple
cf. Cyperus (Motha)	1	40.1	Simple
cf. *Mangifera* (Mango)	9, 16, 14, 24	7.78 – 28.78	Simple
cf. *Zingiber* (Ginger)	8, 16, 20	19.10–40.60	Simple
cf. *Phoenix* (Date Palm)	15, 20, 22, 24	18.29–19.01	Simple
cf. *Macrotyloma* (Horse Gram)	12, 15, 16	20.11–33.23	Simple
f. *Vigna* (sp.)	12, 22	10.47-20.11	Simple
cf. *Sesamum* (Til)	17, 16, 22	4.59 – 8.44	Compound
cf. *Hordeum* (Barley)	24	19.82	Simple
cf. *Eleusine*? (Finger Millet)	15, 24	24.56	Compound
cf. *Sorghum*? (Jowar)	15	20.89	Simple
cf. *Cajanus* (Pigeon Pea)	15	27.84	Simple
cf. *Tamarindus* (Tamarind)	2, 15	7.1-7.58	Simple

The preparation of the starch sample from roots and tubers was done as follows. Fresh plant materials were washed and then peeled. The roots and tubers were then macerated and placed in water. This extract was filtered through cheesecloth; this allows the starch-grains to pass through while retaining larger part of the pulp. The extract was washed and allowed to dry (Piperno and Holst 1998; Piperno *et al.* 2000, 2004).

Once dried, the starch extracts were mounted on a microscopic slide with the help of reverse osmosis water then their characteristic features (See Appendix F) were studied under the Zeiss microscope with a set of polarizing lenses. The characteristics of the modern plants (See Chapter 2 for details) were noted and several pictures were taken. The modern plant collection was used as a reference to identify the starches from the archaeological samples. In addition to the comparative materials studied by me, keys, descriptions and photographs published by other authors were also studied and consulted as a cross reference to support taxonomic identification.

Starch-Grain Analysis of Aceramic Samples

Samples Studied

Seven microliths, one grinding stone and one soil sample were studied from the Aceramic phase at Bagor (See Appendix G). For most of the artifacts two residue samples were collected: (1) residue was collected from tool wash (for tool wash the tool is put into a beaker and rinsed in reverse osmosis water), and (2) residue was collected from tool sonic (tool is put into a beaker with reverse osmosis water and sonicated for 10 minutes). For a few artifacts residue samples were collected from the soil around the tool

and the sample from brushing the tools were also studied. The starch finds will be discussed next. However it must be kept in mind that more modern comparative work must be done before we can securely say if the finds are crop plants or near wild relatives of the plants.

Method

Starch-grain analysis was conducted at the National Museum of Natural History, Smithsonian Institute, Museum Support Center (Details in Chapter2, Chapter 6 and Table 6.1) under the supervision of Drs. Dolores Piperno and Linda Perry. Once the starch was floated with the help of CsCl and cleaned thoroughly with reverse osmosis water to remove any trace of chemicals, they were mounted on a slide. The extract was thoroughly studied by placing the prepared slide on the microscopic stage and moving back and forth at 200X until the entire area under the glass cover was examined. The slide was also examined under polarized light. When a starch granule was located, it was studied under 400X. The starch was rotated using pressure. The starch was drawn in notebook and also photographed. When the examination was complete colorless nail polish was used to seal the slide.

Results

Sample 1

Sample 1 is a microlithic retouched blade tool made on chert (Appendix G, Figures 61.1 – 61.5, 62.1 – 62.6). Residue was collected from tool wash and tool sonic. Four starches (2 from Tool Sonic and 2 from Tool Wash) were retrieved from the tool (Tables 5.3 and 5.4). Two starches were retrieved from Tool Sonic and Tool wash each.

Sample 6

Sample 6 is a microlithic blade tool made on chert (Appendix G, Figures 63.1 – 63.15). Residue was extracted from tool wash and tool sonic (Table 5.5). Tool wash did not produce any starches. Five starches were retrieved from tool sonic.

Sample 7

Sample 7 is an unretouched flake made on chert. Residue was extracted from tool sonic. The residue had no starches.

Sample 9

Sample 9 is a retouched blade made on chert (Appendix G, Figures 64.1 – 64.3). The tools proximal end is broken. Starches were retrieved only from tool sonic (Table 5.6). Two starches were found on the tool.

Sample 10

Sample 10 is a microlithic crescent made on chalcedony (Appendix G, Figures 65.1 – 65.5, 66.1 – 66.6). Residue was extracted from tool wash, tool brush (the residue sticking to the tool was removed with a brush and processed) and tool sonic (Table: 5.7 and 5.8). Residue from tool brush did not have any starches. Residue from tool wash had 4 starches and 2 starches were retrieved from tool sonic.

Sample 11

Sample 11 is an unretouched blade tool made on chert (Appendix G, Figure 67.1 – 67.4). Starches were retrieved from tool wash and tool sonic from the tool. Tool wash did not produce any starches. Two starches were retrieved from tool sonic (Table 5.9).

Sample 13

Sample 13 is an unretouched blade tool made on quartz (Appendix G, Figure 68.1 – 68.5). Residue from the tool was extracted from tool wash and tool sonic. Tool wash did not produce any starches. Four starches were retrieved from tool sonic (Table 5.10).

Sample 16

Sample 16 is a grinder (raw material Quartzite) (Appendix G, Figure 69.1 – 69.28). It is broken and only half of it could be retrieved during the excavation. The grinder was found in the earliest layers at Bagor so it provides the evidence of the earliest plants utilized at the site. Starches were retrieved from the grinder (See Chapter 2 for details) by soaking it in a beaker with reverse osmosis water over night and then

sonication for 30 minutes. Seventeen starches were retrieved from the grinder (Table 5.11).

Sample 20

Sample 20 is soil sample (Appendix G, Figures 70.1 – 70.16). Residue was extracted from the soil sample (See Chapter 2 for details). The soil sample had 8 starches (Table 5.12).

TABLE 5.3: STARCH-GRAINS FROM SAMPLE 1 (TOOL SONIC)

Sample Number	Sample Type	Total Starch	Type of Starch	Starch Size	Description
1	Tool Sonic	2			cf. *Solanum* (Egg Plant) Pericarp Starch = 1 cf. *Solanum* (Eggplant Starch) Damaged = 1
			cf. *Solanum* (Egg Plant) Pericarp Starch	L = 37.97 µm, W = 30.31 µm	Starch is oval shaped. It is thick and wide. Hilum is eccentric here and there are several pits present. The starch has two distinct edges. Under polarize light there are bands, which look like orbits around planets. A depression is present in the center. Also there is a dark band at the edge of the starch granule.
			cf. *Solanum* (Egg Plant) Damaged	L = 41.51 µm, W = 29.55 µm	Starch is oval shaped starch. It is very wide. The starch-grain is similar to above under polarize light. It looks like the starch has been cut or sliced.

TABLE 5.4: STARCH-GRAINS FROM SAMPLE 1 (TOOL WASH)

Sample Number	Sample Type	Total Starch	Type of Starch	Starch Size	Description
1	Tool Wash	2			cf. *Cyperus* (Motha) = 1 cf. *Solanum* (Egg plant) Seed starch =1
			cf. *Cyperus* (Motha)		One oval shaped starch. It is elongate and narrow. Hilum is centric. There are striations in the middle. Lamellae are faint. A very prominent extinction cross is present when polarized
			cf. *Solanum* (Egg Plant) Seed Starch		One bell shaped starch. On rotation looks like a sphere with pressure facets. It is similar to the starches from seed of the egg plant. Hilum is centric and branched like an 'X'. In three dimensions the starch looks round.

TABLE 5.5: STARCH-GRAINS FROM SAMPLE 6 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
6	Tool Sonic	5			Unknown Damaged Starch = 3 Compound Starch = 2
			Unknown Damaged Starch	17.64μm	One elongate starch. It is a damaged starch. Under polarize light it looks like light is emanating from everywhere. It looks partially gelatinized. The extinction cross is disrupted. When rotated it looks inflated.
			Unknown Damaged Starch	19.72μm	Same as above. Only the shape is more like a balloon and it looks like things are sticking out of it
			Unknown Damaged Starch	14.34μm	Tabloid in shape. It looks creased in the center. Lights are radiating from everywhere under polarize light.
			Compound Starch	8.85μm	Diamond shaped starch. There are double lines on the edge. The center looks raised and it rotates like crystals.
			Compound Starch	9.29μm	Same as above. Only there is a depression at the center.

TABLE 5.6: STARCH-GRAINS FROM SAMPLE 9 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
9	Tool Sonic	2			cf. *Mangifera* - 1 Compound Starch – 1
			cf. *Mangifera*		One spherical starch. It has a band on the edge. The band has striations. On one side the starch looks very flat and on the other side it looks raised like a cake with a hole in the middle. Hilum is centric and around the hilum are small dots which under polarize light look like stars in a clear sky. There is light radiating from between the two lines on the edge.
			Compound Starch		Starch has four sides. The edges are distinct and are angular. In three dimensions looks disc shaped. the edges are distinct. There is a band and there are semi-circles in the band. Hilum is centric and there is a grey colored depression in the center.

TABLE 5.7: STARCHES FROM SAMPLE 10 (TOOL SONIC)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
10	Tool Sonic	2			Compound Starch = 1 Unknown Bean Starch = 1
			Compound Starch	3.19μm, 4.78μm	A cluster of small granules are present. Grains have centric hilum with depressions. They rotate like crystals
			Unknown Bean Starch	L=30.58 μm, W=20.05 μm	Elongate and wide starch. Fissure is not well developed -- it is longitudinal in the grain. The grain is bright and has kind of a depression in the center. Lamellae are present. The starch is big and wide –possibly cf. *Cajanus* (Pigeon Pea) or cf. *Macrotyloma* (Horse gram)

TABLE 5.8: STARCHES FROM SAMPLE 10 (TOOL WASH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
10	Tool Wash	3			Compound Starch = 2 Unknown Starch = 1
			Compound Starch	6.74µm	Compound grains, the edges are angular. Hilum is centric and very prominent. There is a depression in the center
			same	7.95µm,	Same as above
			Unknown Starch	11.89µm	One spherical shape starch. It has two lines on the edge. Rotates as round ball. Extinction cross is very prominent under polarized light.

TABLE 5.9: STARCHES FROM SAMPLE 11 (TOOL SONIC)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
11	Tool Sonic	2			Unknown Starch =1 Damaged Starch consistent with Bean = 1
			Unknown Starch	14.78µm	Starch is triangular in shape. Lamellae are faint. Hilum is centric, and extinction cross is not visible. It has double edges and it rotates flat.
			Damaged Bean Starch	L = 30.09µm W = 20.10µm	One damaged bean starch. Very clear fissures, which extend, longitudinally throughout the grain. The starch is elongate and wide. One side is bulkier than the other, on rotation the starch falls on the bulkier side

TABLE 5.10: STARCH-GRAINS FROM SAMPLE 13 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
13	Tool Sonic	4			Compound Starch = 3 cf. *Solanum* (Eggplant) = 1
			Compound Starch	7.5 µm	A disc shaped starch. in three dimensions looks more like a square. The hilum is centric
			Compound Starch	10.53 µm, 8.08 µm, 6.32 µm	Compound starches -- two disc shaped. Hilum is centric. Starch looks lenticular in three dimension. There is a depression in the center
			cf. *Solanum* (Eggplant)	39.63 µm	A damaged elongate and wide starch from eggplant pericarp. The starch has two distinct edges. The starch looks damaged on the edges. The starch has several pits seen on reducing the light

TABLE 5.11: STARCHES FROM SAMPLE 16 (GRINDER)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
# 16	Grinder	17			Unknown Starch = 1 Compound Starch = 1 cf. *Solanum* (Egg plant) = 1 cf. *Zingiber* (Ginger) = 1 *Macrotyloma* (Horse gram) = 1 *Sesamum* (Sesame) = 10 cf. *Mangifera* = 2
			Unknown Starch	10.9µm	One unknown spherical starch. It has two lines on the edges. Looks like a flower. Hilum is centric and there is a depression in the center
			cf. *Zingiber* (Ginger)	19.1µm	One unidentified spherical starch. There are two distinct lines on the edge, hilum is eccentric, lamellae are present
			cf. *Solanum* (Egg Plant)	34.52µm	Starch is oval shaped. It is thick and wide. Hilum is eccentric here and there are several pits present. The starch has two distinct edges. Under polarize light there are bands, which look like orbits around planets. A depression is present in the center. Also there is a dark band at the edge of the starch granule.
			Compound Starch	11.19µm, 7.3 µm	Two compound starches. Both are polygonal and have a centric hilum. There is a raised appearance in the center and the extinction cross is prominent. The edges are angular. On rotation looks like a dice

TABLE 5.11 (CONTD): STARCHES FROM SAMPLE 16 (GRINDER)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
# 16	Grinder	17			Unknown Starch = 1 Compound Starch = 1 cf. *Solanum* (Egg plant) = 1 cf. *Zingiber* (Ginger) = 1 cf. *Macrotyloma* (Horse gram) = 1 cf. *Sesamum* (Sesame) = 10 cf. *Mangifera* = 2
			Macrotyloma (Horse gram)	33µm	Oval shaped starch. Wide with deep fissures. The fissures extends longitudinally, they look like a river valley under polarize light. Lamellae are present.
			Sesamum (Sesame)	5.04µm, 5.35µm	Two disc shaped starches. They have a very open hilum and grey colored area around the hilum which looks like a depression. They rotate like balls with pressure facets. The edges are rounded
			Same as above	5.01µm	Same as above
			Same as above	8.8µm	Same as above
			Same as above	8.67µm, 7.22µm	Same as above
			Same as above	6.01µm	Same as above
			Same as above	7.47, 8.56, 8.44 µm	Same as above

TABLE 5.11 (CONTD): STARCHES FROM SAMPLE 16 (GRINDER)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
# 16	Grinder	17			Unknown Starch = 1 Compound Starch = 1 cf. *Solanum* (Egg plant) = 1 cf. *Zingiber* (Ginger) = 1 *Macrotyloma* (Horse gram) = 1 *Sesamum* (Sesame) = 10 cf. *Mangifera* = 2
			cf. *Mangifera*		One spherical starch. It has a band on the edge. The band has striations. On one side the starch looks very flat and on the other side it looks raised like a cake with a hole in the middle. Hilum is centric and around the hilum are small dots which under polarize light look like stars in a clear sky. There is light radiating from between the two lines on the edge.
			cf. *Mangifera*		Same as above. Except this one has striations on the edge.

TABLE 5.12: STARCH-GRAINS FROM SAMPLE 20

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
# 20	Soil Sample	8			Unknown Damaged Starch = 2 Unknown Starch = 1 cf. Zingiber (Ginger) = 4 cf. Phoenix (Date Palm) = 1
			Unknown Damaged Starch	21.09 µm	One oval shaped starch. It is damaged. Looks like things are sticking out of it. Under polarize light extinction cross is disrupted and light is emanating from everywhere
			Unknown Starch	12.16 µm	Unidentified bell shaped starch. It has two different edge. Looks like it is raised on the edges. There is a depression in the center. One end is rounded and the other end is 'V'shaped.
			cf. *Phoenix* (Date palm)	18.29 µm	One oval shaped starch. Hilum is centric and opens and closes on fine focus. In three dimension it looks very elongate and there is a line running in between. It has faint lamellae.
			cf. *Zingiber* (Ginger)	40.06 µm, 30.08 µm, 30.15 µm	Three starches -- elongate in shape. A small projection at one end and one end is rounded. It has two distinct lines on the edge. There are half concentric circles like striations seen under polarize light emanating from between the two lines on the edge. It has a distinct extinction cross. It looks eye shaped in three dimension

Starch-Grain Analysis of Ceramic Samples

Samples Studied

Eight microliths, 1 grinder and two soil samples (collected from the floor of the (structure) were studied from the Ceramic phase at Bagor (Appendix H). For most of the artifacts two residue samples were collected: (1) residue was collected from tool wash (for tool wash the tool is put into a beaker and rinsed in reverse osmosis water), and (2) residue was collected from tool sonic (tool is put into a beaker with reverse osmosis water and sonicated for 10 minutes). For a few artifacts, residue samples collected from the soil around the tool and the sample from brushing the tools were also studied. The methods used were the same as mentioned above (See Chapter 2 for details). The starch finds will be discussed next. Again it must be kept in mind that more modern comparative work must be done before we can securely say if the finds are crop plants or near wild relatives of the plants.

Results

Sample 2

Sample 2 is a retouched blade tool made on chert (Appendix H, Figures 71.1 – 71.11). Residue from tool sonic was studied. Six starches (4 damaged and 2 unidentified) were retrieved from the tool (Table 5.13). Six starches were retrieved from the residue.

Sample 3

Sample 3 is a flake tool made on chert (Appendix H, Figures 72.1 – 72.12). Residue from tool sonic and tool wash were studied. Tool sonic did not produce any starches (Table 5.14). Tool wash produced eight starches.

Sample 5

Sample is a microlithic crescent made on chert (Appendix H, Figures 73.1 – 73.7 and 74.1 – 74.6). Residue was extracted from tool wash and tool sonic. Seven starches (2 from tool sonic + 5 from tool wash) were retrieved from the tool (Tables 5.15 and 5.16).

Sample 8

Sample 8 is a retouched blade tool made on chert (Appendix H, Figures 75.1 – 75 .5 and 76.1 – 76.10). Residue was extracted from tool wash and tool sonic (Tables 5.17 and 5.18). Six starches (3 from Tool Wash and 3 from Tool sonic) were retrieved from the tool.

Sample 12

Sample 12 is a crescent made on chert (Appendix H, Figures 77.1 – 7.11 and 78.1 – 78.6). Residue was extracted from tool wash and tool sonic. Three starches and a bean starch were retrieved from the tool wash and 5 were retrieved from tool sonic (Tables 5.19 and 5.20).

Sample 14

Sample 14 is a retouched blade tool made on chert (Appendix H, Figures 79.1 – 79.5 and 80.1 – 80.11). Its proximal end is broken. Residue from the tool was extracted from tool wash and tool sonic (Tables 5.21 and 5.22). Ten starches (2 from sonic + 8 from Wash) were retrieved from the tool.

Sample 15

Sample 15 is a retouched blade tool made on chert (Appendix H, Figures 81.1 – 81.3, 82.1, 83.1 – 83.15, 84.1 - 84.5). Residue was extracted from tool sonic, tool brush, soil around the tool and tool wash (Tables 5.23 and 5.24 – Starches from Soil around the Tool: Table 5.25, Starches from Tool Sonic: 5.26). In total 50 starches were retrieved from the tool, including 9 starches from Tool Sonic, 28 Starches from Soil Around the Tool, 5 Starches from Tool Wash and 8 Starches from Tool Brush.

Sample 17

Sample 17 is an unretouched blade tool made on chert (Appendix H, Figure 85.1 – 85.6). Residue was extracted from tool wash and tool sonic. Tool wash did not produce any starches. Tool sonic produced 5 starches (Table 5.27).

Sample 22

Sample is 22 is soil sample collected from the Ceramic level at Bagor (Appendix H, Figure 86.1 – 86.21). Thirty-two starches were retrieved from the soil sample (Table 5.28).

Sample 25

Sample 24 is a Grinder (Quartz) (Appendix H, Figures 88.1 – 87.43). The Grinder was intact and there is evidence of heavy use on the grinder. It was put in a beaker and left over night, then it was sonicated for 30 minutes to extract starch residue. Eighty-six starches were retrieved from the grinder (Table 5.29).

Sample 26

Sample 25 is a soil sample collected from the Ceramic phase at Bagor (Appendix H, Figures 87.1 – 87.7). Eight starches were retrieved from the soil sample (Table 5.30)

TABLE 5.13: STARCH-GRAINS FROM SAMPLE 2 (TOOL SONIC)

Sample number	Sample Type	Total Starch	Type of Starch	Starch Size	Description
2	Tool Sonic	6			Unknown Damaged Starch = 3, cf. *Solanum* (Egg Plant) Damaged = 1 Unknown Starch = 1 cf. Tamarindus (Tamarind) =1
			Unknown Damaged Starch	12.71μm	Starches are tabloid shaped and are damaged. Extinction cross is looks disrupted and light is radiating from everywhere under polarize light. Looks inflated and lenticular in three dimension.
			Unknown Damaged Starch	16.79μm	Starch is damaged. Looks like cross only with rounded rather than straight edge. Looks partially gelatinized, under polarize light-- light is obstructed.
			Unknown Damaged Starch	19.65μm	Starch is damaged. Looks like things are sticking out of it. Looks partially gelatinized under polarize light. When rotated looked inflated.
			cf. *Solanum* (Eggplant) Damaged		One damaged half moon shaped starch. Looks like the starch has been cut into equal halves. The edge is very distinct and has a band and two lines, there are several pits inside and bands are noticed.

TABLE 5.13 (CONTD.): STARCH-GRAINS FROM SAMPLE 2 (TOOL SONIC)

Sample number	Sample Type	Total Starch	Type of Starch	Starch Size	Description
2	Tool Sonic	6			Unknown Damaged Starch = 3, cf. *Solanum* (Egg Plant) Damaged = 1 Unknown Starch = 1 cf. Tamarindus (Tamarind) =1
2	Tool Sonic		Unknown Starch	8.41μm	Triangular shape starch. Hilum is centric and has a depression in the center. Rotates round in three dimension. It does not have pressure facets like Sesamum starches and in the center on rotation there seems to be a lump
			cf. *Tamarindus* (Tamarind)	7.58μm	Spherical starch from Tamarind, there are two distinct lines on the edge, hilum is in the center, in three dimension looks more oval, the starch is bright looking, there is a depression in the center

TABLE 5.14: STARCH-GRAINS FROM SAMPLE 3 (TOOL WASH)

Sample Number	Sample Type	Total Starch	Type of Starch	Starch Size	Description
3	Tool Wash	8			Unknown Damaged Starch = 3, Compound Starch = 2 Unknown Starch = 3
			Unknown Damaged Starch	17.35 µm	One oval shaped starch which looks damaged. It rotates like an American football. Under polarize light it looks like light is emanating from every where.
			Cluster of Compound Starches		A cluster of compound starches. In three dimension look lenticular in shape. Hilum is centric. The starches are so close together they could not be measured.
			Unknown Starch	10.26 µm	One disc shaped starch. Hilum is distinctive in the center and looks like a depression in the center. The starch looks like a star. There is a raised appearance. Under polarize light looks like several small starch granules are joined together. It rotates like a ball.
			Unknown Damaged Starch	15.59 µm, 13.93 µm	Two damaged starches. One is round and the other is elongate. It looks partially gelatinized. Under polarize light the starch looks like a maize cob, and the extinction cross looks disrupted.

TABLE 5.14 (CONTD.): STARCH-GRAINS FROM SAMPLE 3 (TOOL WASH)

Sample Number	Sample Type	Total Starch	Type of Starch	Starch Size	Description
3	Tool Wash	8			Unknown Damaged Starch = 3, Compound Starch = 2 Unknown Starch = 3
			Unknown Starch	14.01 µm, 15 µm	Two unidentified starches - - both spherical in shape. Looks like a flying disc in three dimension. They have pressure facets. Hilum is centric and there are several big holes in the starches.
			Compound Starch	4.4 µm	A disc shaped starch. In three dimension looks more squarish than disc shaped. The hilum is centric

TABLE 5.15: STARCH-GRAINS FROM SAMPLE 5 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
5	Tool Sonic	2			cf. *Solanum* (Egg Plant) = 2
			cf. *Solanum* (Egg Plant)	21.6 and 18.35 µm	Two elongate starches. Both are very flat and very difficult to turn, when turned they look more oval. In three dimension, the center has a raised appearance and there is a line and a crease in the center. Also there is a band along the edge and also numerous rings around the center. Several bands are very prominent under polarize light

TABLE 5.16: STARCH-GRAINS FROM SAMPLE 5 (TOOL WASH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
5	Tool Wash	4			cf. *Solanum* (Eggplant) = 2 Compound grains = 2 Damaged Bean Starch = 1
			Compound Starch	7.44μm 9.17μm	Compound starches with prominent extinction cross. The center has a depression. The extinction cross is prominent in one of the starches. The hilum is centric and the edges of the granules are very angular. Under polarize light they look very similar to starches from rice, they rotate like crystals.
			cf. *Solanum* (Eggplant)	20.27μm	Elongate Starch which are very flat and could not be turned. Looks a little damaged at one end, there are several rings inside the starch seen under polarize light. There is a band at the edge and there are several pits present. Hilum is eccentric
			Same as above	37.1μm	Same as above
			Damaged Bean Starch	31.98μm	Fissures are visible under polarize light. It looks gelatinized under polarize light.

TABLE 5.17: STARCH-GRAINS FROM SAMPLE 8 (TOOL WASH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
8	Tool Wash	3			Unknown Damaged Starch = 3
			Unknown Damaged Starch		Could not determine the shape of the starch. It is partially gelatinized starch and has things sticking out of it. Under polarize light extinction cross is disrupted and light is emanating from every where. Looks inflated and lenticular in three dimension.
			Same as above		Same as above
			Same as above	26.14μm	Same as above

TABLE 5.18: STARCH-GRAINS FROM SAMPLE 8 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
8	Tool Sonic	3			cf. *Zingiber* (Ginger) = 1 cf. *Solanum* (Egg plant) = 1 pericarp Compound grain = 1
			cf. *Zingiber* (Ginger)	32.35μm	Elongate with a projection in the one end and the other end is more rounded. When rotated looks very elongate and very narrow. Lamellae are present but faint. There is a band on the edge and it is surrounded by another line. Hilum is eccentric.
			Compound grain	6.84μm	Disc shaped grain, it is raised in the center, extinction cross is very prominent in the center like an x under polarize light, in three dimension looks more bell shaped than disc
			cf. *Solanum* (Egg plant)	16.62μm	One elongate starch. It is very flat and very difficult to turn, when turned they look more oval. Also there is a band along the edge and also numerous rings around the center. There are two lines on the edges, there are bands seen under polarize light. There is also evidence of small pits in the starch. Looks a little damaged under polarize light. Hilum is eccentric and lamellae are very faint

TABLE 5.19: STARCH-GRAINS FROM SAMPLE 12 (TOOL SONIC)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
12	Tool Sonic	5			*Vigna* (sp.). = 1 *Macrotyloma* (Horse Gram) =1 Compound Starch = 2 Damaged Starch = 1
			Damaged Starch	12.46μm	Oval shaped starch. It rotates like a ball and under polarized light looks damaged.
			Compound Starch	5.5μm, 4.93μm	Two compound starches which are disc shaped and look like crystals when turned
			Vigna (sp.).	10.47μm	Spherical shaped starch. It has two edges and has two distinct lines. There is a 'V' shaped fissure which extends latitudinally throughout the grain.
			Macrotyloma (Horse Gram)	L= 20.11μm, W = 27.87μm	Wide and elongate shaped starch. Fissure is present, and they look like a river valley, lamellae are prominent. The starch-grain is bulkier on one side and when rotated it falls on that side.

TABLE 5.20: STARCH-GRAINS FROM SAMPLE 12 (TOOL WASH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
12	Tool Wash	3			Unknown Bean Starch = 1 Compound Starch = 1 Starch Granules = A Cluster
			Unknown Bean Starch	L= 16.47μm, W = 14.10 μm	One elongate shaped bean starch. It is elongate in shape and there is a fissure on close observation. Lamellae are present
			Compound Starch	7.47μm	Compound starch -- polygonal in shape. Rotates like a diamond crystal. The edges are angular.
			Starch Granules	4.59, 5.04, 6.03, 5.15, 6.74, 5.4, 7.44, 5.51, 6.27, 5.41, 8.23, 7.05, 6.51, 4.43, 5.71, 4.86, 7.86, 7.79, 9.04, 6.86, 5.04, 7.43, 6.04, 7.51, 7.64, 6.87, 8.41, 4.6, 3.91μm	A cluster of starch granules. Rotate like dice. Extinction cross is visible, it is raised in the center.

TABLE 5.21: STARCH-GRAINS FROM SAMPLE 14 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
14	Tool Sonic	2			cf. *Mangifera* (Mango) = 2
			cf. *Mangifera* (Mango)	14.69 µm	Spherical in shape, looks like a cake with a hole in the center, there is a big band at the edge and it has striations, hilum is centric and is raised, when the light is reduced to see the surface features more clearly there are several dots in the center around the hilum, which under polarize light look like tiny stars in a clear sky, looks hemispherical when turned
			Same as above	14.79µm	same as above

TABLE 5.22: STARCH-GRAINS FROM SAMPLE 14 (TOOL WASH)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
14	Tool Wash	8			cf. *Solanum* (Eggplant) = 4 (1 seed and 3 pericarp) Damaged Starch = 1 Unknown Starch = 3
			cf. *Solanum* Eggplant (Eggplant pericarp)	15.93µm	Starch is elongate in shape. It looks some what damaged. Rotates very flat. There is a band on the edge which looks raised. There are two rings inside the starch and there is a big depression in the center. There are several pits in the starch
			Same as above	23.53µm	Same as above -- only several rings are seen inside the starch
			cf. *Solanum* Eggplant (Eggplant seed)	22.48µm	Bell shaped starch. Hilum is centric and has a small 'X' shaped fissure. The edge has two lines. Under polarize light looks like light is emanating from between the two lines on the edge.
			Unknown Damaged Starch	15.52µm	Bell shaped damaged starch. It is partially gelatinized. Things are sticking out of it, extinction cross is disrupted.

TABLE 5.22 (CONTD.): STARCH-GRAINS FROM SAMPLE 14 (TOOL WASH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
14	Tool Wash	8			cf. *Solanum* (Eggplant) = 4 (1 seed and 3 pericarp) Damaged Starch = 1 Unknown Starch = 3
			Unknown Starch	4.51µm	Spherical shaped starch. Hilum is centric and there is a depression in the center
			Same as above	7.55µm	Same as above
			Same as above	6.76µm	Same as above

TABLE 5.23: STARCH-GRAINS FROM SAMPLE 15 (TOOL BRUSH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Tool Brush	8			Compound Starch = 6 Unknown Starch = 1 Unknown Damaged Starch = 1
			Compound Starch	5.5 and 5.86 μm	Four compound grains. 3 of them are disc shape and one is triangular in shape. Hilum is centric and forms a depression in the center. The grains rotate flat and the center part is elevated
			Compound Starch	5.66μm	Starch is square in shape. It has centric hilum and the edges are pointed. It turns flat like paper.
			Compound Starch	7.14μm	Starch is tabloid in shape. Hilum is in the center and the edges are round and there is a depression in the center.
			Unknown Starch	8.9μm	Starch is spherical shape. hilum is in form of a dot in the center. Lamellae are faint and present only on the sides. Pressure facets are present. They looks like kidney beans when rotated, looks very similar to some of the round grains from the beans
			Damaged Starch	25.61μ m	One very damaged and partially gelatinized starch. It is elongate in shape and is wide, extinction cross is disrupted. Lamellae are present and on rotation turns flat like paper

TABLE 5.24: STARCH-GRAINS FROM SAMPLE 15 (TOOL WASH)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Tool Wash	5			*Sesamum* (sesame) = 5
			Sesamum (sesame)	10.42μm, 9.58 μm	Angular with rounded edges, five sided, hilum is centric and very distinct - it looks like a depression, the grains rotate as small round balls with pressure facets, in three dimension look like disc
			Same as above	4.08μm, 3.92μm and 5.10μm	Same as above, A cluster of grains, very tiny, mostly triangular in shape, some are disc shaped also, hilum is centric, rotates very flat

TABLE 5.25: STARCH-GRAINS FROM SAMPLE 15 (SOIL AROUND THE TOOL)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
15	Soil Around Tool	28			Compound Starch = 18 cf. *Cajanus* (Pigeon Pea) = 2 *Macrotyloma* (Horse gram) = 2 Damaged Bean Starch = 1 cf. *Phoenix* (Date Palm) = 1 cf. *Tamarindus* (Tamarind) = 2 Unknown Starch = 1 Possibly Finger millet =1
			Unknown Starch	15.94μm	Spherical shape, faint lamellae, hilum not seen
			Compound Starch	4.9μm and 5.2μm	Two starches -- both polygonal in shape. The edges are rounded. In three dimension look like a discs. The hilum is in the center and forms kind of a depression.
			Same as above	4.5μm	One disc shaped starch. It has centric hilum and the edges look very angular
			Same as above		One disc shaped starch. It has centric hilum and the edges look very angular. They rotate like crystal.
			Same as above	4.9μm	One tabloid shaped starch. It has centric hilum. It has two distinct edges and rotates very flat.

TABLE 5.25 (CONTD.): STARCH-GRAINS FROM SAMPLE 15 (SOIL AROUND THE TOOL)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Soil Around Tool	28			Compound Starch = 18 cf. *Cajanus* (Pigeon Pea) = 2 *Macrotyloma* (Horse gram) = 2 Damaged Bean Starch = 1 cf. *Phoenix* (Date Palm) = 1 cf. *Tamarindus* (Tamarind) = 2 Unknown Starch = 1 Possibly Finger millet =1
			Compound Starch Cluster	4.5μm, 4.9μm, 5.6μm	Four starches -- polygonal in shape The edges are rounded. They rotate like balls with pressure facets on them. The hilum is in the center and forms kind of a depression. Disc shaped in three dimension.
			Same as above		Four starches all clustered together. On rotation looks like dices. They are raised in the center. Extinction cross is prominent.
			Same as above		One disc shaped starch. It has centric hilum. The edges look very angular.
			Same as above		Two triangular in shape starches. There is a depression in the center. The granules rotate like dice. Extinction cross is visible under polarize light and has a raised appearance.
			Same as above		One disc shaped starch. It has centric hilum and the edges look very angular.

TABLE 5.25 (CONTD.): STARCH-GRAINS FROM SAMPLE 15 (SOIL AROUND THE TOOL)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Soil Around Tool	28			Compound Starch = 18 cf. *Cajanus* (Pigeon Pea) = 2 *Macrotyloma* (Horse gram) = 2 Damaged Bean Starch = 1 cf. *Phoenix* (Date Palm) = 1 cf. *Tamarindus* (Tamarind) = 2 Unknown Starch = 1 Possibly Finger millet =1
			Same as above	5.9μm	One polygonal starch. The edges are rounded. In three dimension it is disc shaped. It has pressure facets. The hilum is in the center and forms kind of a depression.
			Macrotyloma (Horse gram)	L = 33.23μm W= 27.23μm	One elongate shaped starch. It is very thick and wide. It has thick fissures present. It looks like deep cut marks are present. Very thick lamellae are present. The starch is bright looking, with depression in center.
			Damaged Bean Starch		One elongate shaped starch. The edge has a raised appearance and there is a depression in the center. Rotates like peanut. Light is emanating from everywhere under polarize light.

TABLE 5.25 (CONTD.): STARCH-GRAINS FROM SAMPLE 15 (SOIL AROUND THE TOOL)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Soil Around Tool	28			Compound Starch = 18 cf. *Cajanus* (Pigeon Pea) = 2 *Macrotyloma* (Horse gram) = 2 Damaged Bean Starch = 1 cf. *Phoenix* (Date Palm) = 1 cf. *Tamarindus* (Tamarind) = 2 Unknown Starch = 1 Possibly Finger millet =1
			cf. *Tamarindus* (Tamarind)	7.1, 7.8µm	Spherical on rotation looks inflated and lenticular in shape, a small dot shaped hilum present in the center, has pressure facet and there is a raised small circle in the center, lamellae are faint, one of starch looks bean shaped in three dimension, other looks like a hat hollow on one end and pointed on the other
			Compound Starch cluster		Compound grain with several starches granules. They are clustered together, could not separated.
			Possibly Finger Millet		Compound grain with several starch granules, clustered together. They could not separate at all. The granules are hemispherical in shape.

TABLE 5.25 (CONTD.): STARCH-GRAINS FROM SAMPLE 15 (SOIL AROUND THE TOOL)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Soil Around Tool	28	Damaged Bean Starch		One elongate and narrow in shape starch. Under polarize light the fissures are evident. The starch looks very damaged
			cf. *Cajanus* (Pigeon Pea)	L = 27.84µm W = 26µm	One oval shape starch. It has very deep fissures. Fissures give the impression of raised lip. Lamellae are present all over the starch, looks like concentric lines.
			cf. *Phoenix* (Date palm)	18.95µm	Starches are elongate in shape. Lamellae are thin and present only in the center and thick on the edges. It has pen hilum in the center which opens and closes on fine focus, on rotation it looks like foot ball with a line in the center.
			Macrotyloma (Horse gram)	33.22µm	One elongate shape shaped starch. Fissures are present and give a valley like appearance. Very, very thick lamellae present. There is a depression in the center. The grain is bright looking

TABLE 5.26: STARCH-GRAINS FROM SAMPLE 15 (TOOL SONIC)

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
15	Tool Sonic	9			Compound Starch = 1 *Sesamum* (Sesame) = 2 cf. *Phoenix* (Date Palm) = 1 Unknown Starch = 2 Damaged Bean Starch = 1 Damaged Starch = 1 Possibly *Sorghum* =1
			Compound Starch	7.36μm	One compound grain. It is triangular in shape. Hilum is centric and forms a depression in the center. The grains rotate flat and the center part is elevated
			Sesamum (Sesame)	8.1μm, 9.0 μm	Two starch-grains – polygonal in shape. They have rounded edges. Hilum is centric and very distinct - it looks like a depression. The grains rotate as small round balls with pressure facets. In three dimension look like disc.
			cf. *Phoenix* (Date Palm)	18.81μm	One oval shaped starch. Hilum is centric and opens and closes on fine focus. In three dimension it looks very elongate and there is a line present in the center. Lamellae are present but faint.

TABLE 5.26 (CONTD): STARCH-GRAINS FROM SAMPLE 15 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
15	Tool Sonic	9			Compound Starch = 1 *Sesamum* (Sesame) = 2 cf. *Phoenix* (Date Palm) = 1 Unknown Starch = 2 Damaged Bean Starch = 1 Damaged Starch = 1 Possibly *Sorghum* =1
			Unidentified Starch	10.32μm	Spherical starch-- has two different lines on the edges. Under polarize light radiates from between the two distinct line. It rotates like a square. Under three dimension it looks like a flying disc.
			Possibly Sorghum	20.89μm	Spherical starch -- rotates squarish. Looks like a dice in three dimension. The starch has very distinct holes. Under polarize light looks like has different bands.
			Unidentified Starch	15.58μm	Oval starch -- looks like a sweet potato shaped. One end is rounded the other end is more pointed but rounded.
			Damaged Bean Starch	18.41μm	Oval bean starch. It looks damaged. Fissure visible under close observation. It is partially gelatinized.
			Damaged Starch	18.14μm	One damaged elongate shaped starch. Extinction cross is disrupted.

TABLE 5.27: STARCH-GRAINS FROM SAMPLE 17 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
# 17	Tool Sonic	5			Compound Starch = 2 Damaged Unknown Starch = 1 Damaged Seed Starch = 1
			Compound Starch	8.82μm	Compound grain -- triangular in shape. Hilum is centric and very distinct. The grain rotates as small round balls with pressure facets. Looks like a disc in three dimension
			Compound Starch	2.2μm, 6.4μm	A cluster of grains, small granules usually five sided with centric hilum. They rotate like crystals
			Damaged Seed Starch	13.91μm	Damaged, tabloid shaped seed from grass. Grain is inflated in three dimensions. They are probably damaged from grinding up. Looks like the inside is scooped off. Extinction cross is disrupted, under polarize light emanating from all directions.

TABLE 5.27 (CONTD.): STARCH-GRAINS FROM SAMPLE 17 (TOOL SONIC)

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
# 17	Tool Sonic	5			Compound Starch = 2 Damaged Unknown Starch = 1 Damaged Seed Starch = 1
			Damaged Unknown Starch	19.01µm	One partially gelatinized starches, elongated in shape, looks like things are sticking out of the starch, hilum not visible, rotates like football, under polarize light emanating from everywhere
			Damaged Unknown Starch	19.91µm	One partially gelatinized starches, elongated in shape, hilum not visible, rotates like paper, looks like there is a fissure (cut mark) on it and under polarize light emanating from between the fissure (cut mark)

TABLE 5.28: STARCH-GRAINS FROM SAMPLE 22

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
22	Soil	32			*Vigna* spp. - 8 Unknown Starch - 2 Unknown Damaged - 3, Ground up seed starches - 7, *Sesamum* (sesame) - 6, cf. *Phoenix* (Date palm) - 2, *Vigna* (Urd) - 1, *Vigna* (Mong) - 1 Compound grains - 2
			Sesamum (Sesame)	7.51µm, 5.67µm, 4.81µm, 4.59µm, 7.16µm, 7.1µm	Six polygonal starches. They have centric hilum. Lamellae present in the center. In three dimension looks like a ball. The edges are more rounded than angular and center is grayish looking.
			Vigna sp.	Average 20 µm	Five oval and 3 round starches from Vigna species. Lamellae are faint and the fissures are not very deep rarely extend throughout the grains. The grains are very dull looking and seldom radiate light under the polarizer.
			Unknown Starch	27.1µm	One unknown oval starch. One end is rounded and the other end is tapering. Lamellae are very faint, hilum not seen. The extinction-cross not seen. The starch when rotated looks like a person with a fat belly. There are number of pits on the starch

TABLE 5.28 (CONTD.): STARCH-GRAINS FROM SAMPLE 22

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
22	Soil	32			cf. *Vigna* spp. - 8 Unknown Starch - 2 Unknown Damaged - 3, Ground up seed starches - 7, cf. *Sesamum* (sesame) - 6, cf. *Phoenix* (Date palm) - 2, cf. *Vigna* (Urd) - 1, cf. *Vigna* (Mong) - 1 Compound grains - 2
			Unknown Starch	30. 4μm	Elongate starch-- looks like above unknown starch except the lamellae are much fainter and there are no tapering ends. One side is straight and the other side is more bulky when rotated the starch falls always on the bulkier side. In three dimension looks more quadrangular, one side looks flat and the wider side looks more rounded
			Ground up seed starches		Tabloid shaped starches. Looks like tumbled stone. Looks like they have been ground. The extinction cross is disrupted. Hilum is eccentric the edges are jagged. On turning looks very inflated and lenticular in shape. Under polarizer -- light is emanating from everywhere
			Same as above		same as above

TABLE 5.28 (CONTD.): STARCH-GRAINS FROM SAMPLE 22

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
22	Soil	32			*Vigna* spp. - 8 Unknown Starch - 2 Unknown Damaged - 3, Ground up seed starches - 7, *Sesamum* (sesame) - 6, cf. *Phoenix* (Date palm) - 2, *Vigna* (Urd) - 1, *Vigna* (Mong) - 1 Compound grains - 2
			same as above		Same as above. Except it looks more damaged, when light is reduced and it looks like the inside portion have been scooped out. Thus there is a kind of a depression in the center. Hilum could not be seen.
			same as above		Same as above
			same as above		Same as above
			same as above		Same as above
			same as above		Same as above. Except the starch looks very battered. Hilum is present and eccentric. It is much bigger than the other starches observed so far in the sample and has very rough edges. The inside is jagged looking. One of edge looks more pointed than the others
			Unknown Damaged Starches		Two damaged starches, both are hexagonal in shape. Look partially gelatinized.

TABLE 5.28 (CONTD.): STARCH-GRAINS FROM SAMPLE 22

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
22	Soil	32			*Vigna* spp. - 8 Unknown Starch - 2 Unknown Damaged - 3, Ground up seed starches - 7, *Sesamum* (sesame) - 6, cf. *Phoenix* (Date palm) - 2, *Vigna* (Urd) - 1, *Vigna* (Mong) - 1 Compound grains - 2
			Unknown Damaged starch	15.97μm	Partially gelatinized and damaged starch. It is shapeless. The extinction cross is much disrupted. Under polarizer light emanating from everywhere. Looks like the starch has external growth to it.
			Compound Starches		Two polygonal starches. They have well defined pressured edges. On rotation looks like crystals and has pressure facets. They are very angular. Hilum is centric. In both, the surface looks layered.
			cf. *Phoenix* (Date palm)		Oval shaped starch. Hilum is in the center and closes and opens on fine focus. Lamellae are present but faint. A dark band is seen on the edge. When rotated looks very narrow and elongate and there is a faint line present in the center.

TABLE 5.28 (CONTD.): STARCH-GRAINS FROM SAMPLE 22

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
22	Soil	32			Vigna spp. - 8 Unknown Starch - 2 Unknown Damaged - 3, Ground up seed starches - 7, Sesamum (sesame) - 6, cf. Phoenix (Date palm) - 2, *Vigna* (Urd) - 1, *Vigna* (Mong) - 1 Compound grains - 2
			Vigna (Urd)		One round starch. It is very bright looking starch. Hilum is centric and there is a raised spot on the hilum. The grain looks under pressure when rotated. When you look at it from different angles the hilum looks closed.
			Vigna (Mong)		One round Starch. It is very dull. Hilum is centric and there is a tiny fissure, and it is stellate. There is no pressure when the grain is rotated.

TABLE 5.29: STARCH-GRAINS FROM SAMPLE 24

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
24	Grinder	86			Unknown Damaged Starch = 1 cf. *Mangifera* (Mango) = 7 cf. *Phoenix* (Date Palm) =1 Unknown Starch = 1 cf. *Solanum* (Egg Plant) seed starch = 70 cf. *Solanum* (Egg Plant) pericarp starch = 6 cf. Finger Millet (?) cf. Hordeum (Barley) = 1
			cf. Eleusine? (Finger Millet)	Total size = 24.56μm Starch granule sizes = 11.84μm, 7.34μm, 4.84μm, 7.48μm, 8.97μm	Starch granules stuck together (could not be separated). Three granules are attached together in the picture. Five granules were attached together but on pushing with the pin for rotation 2 separated (these granules are triangular in shape and on rotation look lenticular).
			Unknown starch	28.99μm	Narrow and Elongate starch. It looks lenticular in shape on rotation. Could not be rotated, looks like there are two lines on the edge of the starch. Under polarizer light is emanating from everywhere
			Unknown Damaged Starch	31.84μm	Damaged and partially gelatinized starch. Looks like there are a number of holes in the starch and also looks like things are sticking out of it. Under polarizer light is emanating from the holes.

TABLE 5.29 (CONTD.): STARCH-GRAINS FROM SAMPLE 24

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
24	Grinder	86	cf. *Mangifera* (Mango)	17.93μm, 24μm, 10.41μm, 8.89μm, 7.78μm, 26.08μm, 28.78μm	Consistent with Mango, hemispherical in shape, has two lines on the edge and a dark band near the center, lamellae are faint, on rotation looks like a ball, there are several dots and pits all around the hilum which is centric and the dots look like stars in clear sky, looks like there are striations on the edge, the starch looks like a cake with a big hole in the center, on rotation looks hat shaped
			cf. *Phoenix* (date palm)	19.01μm	One oval shaped starch, hilum is centric, and opens and closes on fine focus, in three dimension it looks very elongate and there is a line running in between, faint lamellae
			cf. *Solanum* (Egg plant pericarp starch)	37.31μm, 15.91μm, 21.56μm, 40.84μm	1 oval shaped starch from pericarp of egg plant, it is wide, there are thick bands, hilum is eccentric, there are several pits in the starch, the starch has two distinct edges, under polarize light there are bands, which look like orbits around planets, there is a depression in the center

TABLE 5.29 (CONTD.): STARCH-GRAINS FROM SAMPLE 24

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
24	Grinder	86			Unknown Damaged Starch = 1 cf. *Mangifera* (Mango) = 7 cf. *Phoenix* (Date Palm) =1 Unknown Starch = 1 cf. *Solanum* (Eggplant) seed = 70 cf. *Solanum* (Eggplant) pericarp = 6 cf. Eleusine (?) = 1 cf. Hordeum (Barley)
			cf. *Solanum* (Egg plant seed starch)	37.96, 21.97, 20.01, 23.39, 22.68, 18.09, 13.77, 18.43, 31.06, 8.76, 14.07, 9.56, 14.69, 19.72, 17.42, 15.68, 19.25, 26.74, 21.33, 25.03, 18.04, 27.51, 24.11, 21.7,19.84, 7.17,11.29, 13.28, 4.04, 23.79,28.23, 28.26, 21.16, 26.19,14.2, 9.07, 16.03, 18.5,23.15,16.88,16.79,19.27, 20.94,19.29,20.08,22.63, 27.28, 32.5,16.21,25.04,14.78,14.82,11.73, 24.0, 24.53, 40.57 16.51, 33.86, 15.59, 14.03,17.42,16.52µm	Bell shaped starches. Hilum is centric and branched like an 'X'. In three dimension looks like a hemisphere with pressure facets. The extinction cross is prominent under polarize light. The last 4 are damaged and have small holes in them which make them look like hub caps.

TABLE 5.29 (CONTD.): STARCH-GRAINS FROM SAMPLE 24

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
24	Grinder	86			Unknown Damaged Starch = 1 cf. *Mangifera* (Mango) = 7 cf. *Phoenix* (Date Palm) =1 Unknown Starch = 1 cf. *Solanum* (Eggplant) seed = 70 cf. *Solanum* (Eggplant) pericarp = 6 cf. Eleusine (?) = 1 cf. Hordeum (Barley)
		86	cf. *Hordeum* (Barley)	19.82 21.11μm	Grains are simple and circular to oval. In three dimensions they look more lenticular. Hilum is centric. Lamellae are present. The grains have a deep crater like appearance and resembling the cells of a beehive.
			cf. *Sorghum* (Jowar)	22.68, 26.56, 29..99, 26.19, 39.84,	Grains are simple spherical Shape. When rotated they look like dices. Lamellae are present. Some of the grains when turned are round and have a band around the center. There is a depression in the center and there are striations all around the center (looks like cut kiwi fruit). Hilum is centric and some have fissures (X in shape and sometimes stellate). Very distinct extinction cross under polarize light, the grains are dull and have a stony appearance.

TABLE 5.30: STARCH-GRAINS FROM SAMPLE 25

Sample no.	**Sample Type**	**Total Starch**	**Type of Starch**	**Starch Size**	**Description**
25	Soil Sample	8			Compound Starch = 2 Unknown Starch = 6 cf. *Solanum* (Egg plant) seed = 1
			Compound Starch	5.86μm	Disc shaped compound starch. Hilum is centric and there is a depression in the center. When turned looks like crystals
			Compound Starch	4.72μm	Same as above except there is a depression in the center.
			Unknown Starch	18.82μm	One elongate starch with centric hilum. It opens and closes on fine focusing. Presence of lamellae. Looks narrower in three dimension.
			Unknown Starch	20.03μm	Same as above

TABLE 5.30 (CONTD.): STARCH-GRAINS FROM SAMPLE 25

Sample no.	Sample Type	Total Starch	Type of Starch	Starch Size	Description
			Same as above		Same as above
			cf. *Solanum* (Eggplant)		Bell shaped starches. Hilum is centric and branched like an 'X'. In three dimension looks like a hemisphere with pressure facets. The extinction cross is prominent under polarize light.
			Unknown Starch		Several (at least 24) lumped together-- grey colored starches. They disc shaped, they have bands and they have double edges. When turned look like round balls. There is a pressured look at the center. The hilum is in the center and the center looks like cut kiwi fruit.
			Same as above	7.09μm	Unidentified round starch. Rotates like a ball. Lamellae are present. There are small holes like in the starch which is visible under polarize light.

Plant Assemblage at Bagor

It appears that the inhabitants of Bagor were subsisting on a mixed economy during the Aceramic phase. They exploited both vegetable and seed crops including: roots like possibly *Zingiber* (Ginger) and *Cyperus* (Motha), vegetable like possibly *Solanum* (Eggplant) and seed like *Sesamum* (Sesame), beans/pulses like *Macrotyloma* (Horse gram), they also exploited fruits like possibly *Phoenix* (Date Palm) and *Mangifera* (Mango).[1] A large number of unidentified compound grains have also been found from the samples. This indicates that the Aceramic people might have collected other kinds of wild grasses for their subsistence also.

By the Ceramic period there is evidence of intensification of plant use. New plants are added to the economy. We have evidence of fruits like possibly *Tamarindus* (tamarind) along with cf. *Phoenix* (Date Palm) and *Mangifera*, beans/pulses such as *Vigna* species and possibly *Cajanus* (Pigeon Pea) are added to the list with *Macrotyloma* (Horse gram)[1]. Although more research needs to be done on millets both local and adopted in India, one of the tools (Sample 15) also has starches possibly *Eleusine* (?) (Finger Millets) and *Sorghum* (Jowar).

[1] (Much more work on the ground collecting the wild and domesticated taxa and studies in the laboratory must be conducted before we can say for sure if the plants found at Bagor are crop plants or near wild relatives).

Discussion: Evidence at Bagor versus Finds by Others in South Asia

According to Fuller (2002: 292) there is a clear evidence for a number of crop origins in South Asia including the tropical pulses, as well as several localized millets, cotton and also most possibly sesame (Table 5.1). However, the important problem that must be considered is this: if these crops share origins in South Asia, where more specifically were they domesticated? As Fuller (2002) points out, the modern botanical-geographical evidence is often inadequate to localize these regions with certainty. In addition, there are cases in which it seems likely that the wild progenitors has become extinct in its primary habitat due to the extensive spread of agriculture and to population pressure and to changes in the environment in the sub continent (Fuller 2002). One important candidate for this situation according to Fuller (2002) is the tropical pulse *Macrotyloma uniflorum (Lam.)*. This pulse is well represented in archaeological finds across India, from mid-third millennium B.C. (with the archeological site for earliest occurrence being Khunjhun, in the Vindhayan Plateau – Kajale 1991; Saraswat 1992) (Figure 5.1), but is of unclear regional origin since wild populations are not reported in any regional floras (Fuller 2002). It has been also reported from the Harappan site of Burthana Tigranan in Harayana (Wilcox 1992), and Southern Neolithic sites of Andhra and Karnataka (Fuller 2004). It is also cultivated in Africa but has not been noted as wild there (Verdcourt 1971; Smartt 1990). Although more comparative studies need to be done, the results of the present research clearly suggests that *Macrotyloma* (Table 5.2) was being exploited by settlers at Bagor by cal. years 5,700 B.C.

Another important group of Indian crops is the pulses in the genus *Vigna* (Figure 5.1) including V. *radiata* (L.) R. Wilczek, and V. *mungo* (L.) Hepper, can now be considered to have distinct geographical origins (Fuller 2002; Fuller *et al.* 2004). Both occur in profuse in western Himalayan foothills in secondary habitat and Western Ghats on the Peninsula (Arora *et al.* 1973; Lukoki and Otoul 1980; Miyazaki 1982; Chandel *et al.* 1984; Fuller 2002; Fuller *et. al.* 2004; Smartt 1985; 1990; Lawn 1995 and Kaga *et al.* 1996). *Vigna* (Table 5.2) species were exploited by the prehistoric settlers at Bagor as early as cal. years 4,500 B.C.

Another major pulse *Cajanus Cajun* has been alternatively attributed to African origin (De Candolle 1886; Langer and Hill 1991; Sundararaj and Thulasidas 1993) on the basis of mistaken botanical evidence and a disputed find of a single archaeological specimen in Egypt. Its wild progenitor *Cajanus cajanifolia* is now well established through morphological and botanical study to occur in a very limited area in Bastar in Orissa, India (De 1974; van der Maeson 1980, 1986, 1990, 1995; Smartt 1985, 1990; Jha and Ohri 1996). *Cajanus Cajun* (Pigeon Pea) seeds occur in the later levels at Sanganakallu in South India (Fuller 2004). This occurrence together with its occurrence in Peddamudiyam, Cuddapah District of Karnataka (Venkatasubbhaiah and Kajale 1991) and Tuljapur Garhi, Maharashtra (Kajale 1996) suggests that the pulse began to spread out of its region of origin around the second millennium B.C. Starch-grain analysis of the samples from Bagor suggests that this process might have begun by the third millennium B.C.

In India modern ethnographic studies suggests that a wide variety of plant food – roots and tubers (such *Cyperus rotundus*, *Zingiber officinale Rosc.*, etc.) and fruits (such

as Magifera, *Phoenix dactylifera*, *Tamarindus indica* (L.), etc.) have served as important food resources of hunter-gatherers and early farmers during prehistoric period (Chatterjee *et al.* 1990; Chatterjee 1991; Maheshwari and Singh 1965; Meadow 1996, 1998; Fuller 2001). Many such plant resources have also been referred in early texts such as *Yajurveda* and *Brahmanas* dated to 1st millennium B. C. (Mehra and Arora 1985; Vishnu Mittre 1989; Fuller 2001). It is quite possible that many of these plants were exploited as wild plants, passing through several levels of man-plant relationship; from acquaintance through excessive exploitation they were later domesticated. Evidence of use of possibly *Mangifera* (Mango), *Zingiber* (Ginger) and *Phoenix* (Date palm) has been found at Bagor. Although more research needs to be done to accurately say if these are crop plants or their wild relatives, the results are nonetheless important for Indian archaeology.

The geographical origin's of Sesame is disputed. It is often suggested that sesame was domesticated in Africa (Mehra 2000; Nayar and Mehra 1970). However wild population studies (conducted by Ihlenfeldt and Grabow-Seidensticker 1979; Bedigian and Harlan 1986, including an analysis of seed protein profiles by Bedegian *et al.* 1985) and recent reviews of sesame finds at the Harappan sites (Fuller 2002, Fuller and Madella 2001 and Fuller 2003) support the South Asian origin of the seed. At the site of Bagor there is evidence of exploitation of cf. *Sesamum* (Sesame) from the earliest settlement. This study shows that sesame (more studies need to be done to say if the crop was domesticated or its wild progenitor was used) was exploited as early as cal. years 5,700 B.C in the Mewar region of Rajasthan.

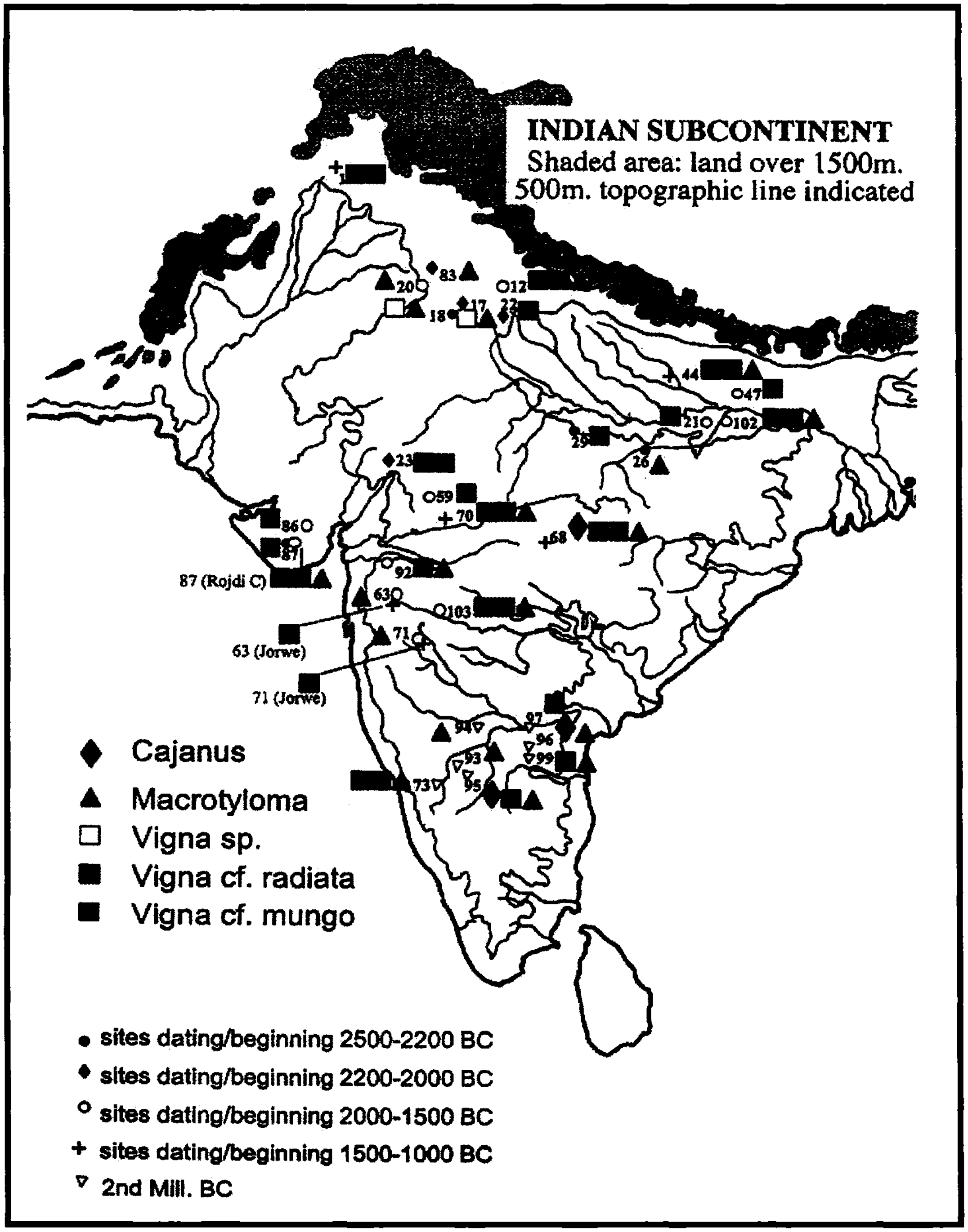


Figure 5.1: Map Showing Archaeological Distribution of Tropical Pulses in India (After Fuller 2002, pp.313, Figure 5)

More research needs to be done and more species of millets needs to studied, before something can be conclusively said about the exploitation of cf. *Eleusine* (Finger Millet) and cf. *Sorghum* at Bagor. Yet it is important to note that few starches from cf. *Eleusine* (Finger Millet) and cf. *Sorghum* have been found at Bagor. Evidence of these plants which are both African in origin has been claimed at a number of sites in India (Lone *et al.* 1991; Possehl 1986, 1998; Weber 1991, 1992; Ratnagar 1994; Meadow 1996; Vishnu-Mittre 1971, See Figure 5.2). The claims are, however, very controversial (Willcox 1992; Rowley-Conwy *et al.* 1997; Fuller 2002). These crops were utilized by the Ceramic-phase (cal. years 4,500 B.C.) at Bagor.

One of the most interesting finds at Bagor is the presence of starches from seeds and pericarp of cf. *Solanum* (Eggplant). To the best of my knowledge this is the first evidence of eggplant from any archaeological site in the world.

As mentioned in Chapter 1, we know that the development and spread of agriculture and pastoralism in South Asia is a very complex phenomenon that took place over a course of more than nine millennia (Allchin 1982; Korrisettar et al. 2002; Liversage 1983; Meadow 1996, 1998, Singh 2002) in several different areas of the region (See Figure 1.1). As mentioned above, the origin of agriculture in the subcontinent is obscure. Liverage (1989) proposed one of the simplest classifications of four Neolithic regions in South Asia which were hypothesized to have had distinct prehistoric agricultural traditions that were based on different but overlapping kinds of crops. They included (as mentioned in Chapter 1) Baluchistan, the Indus Valley, and a large west central Indian region extending from the Aravallis to the Deccan. This division has however been

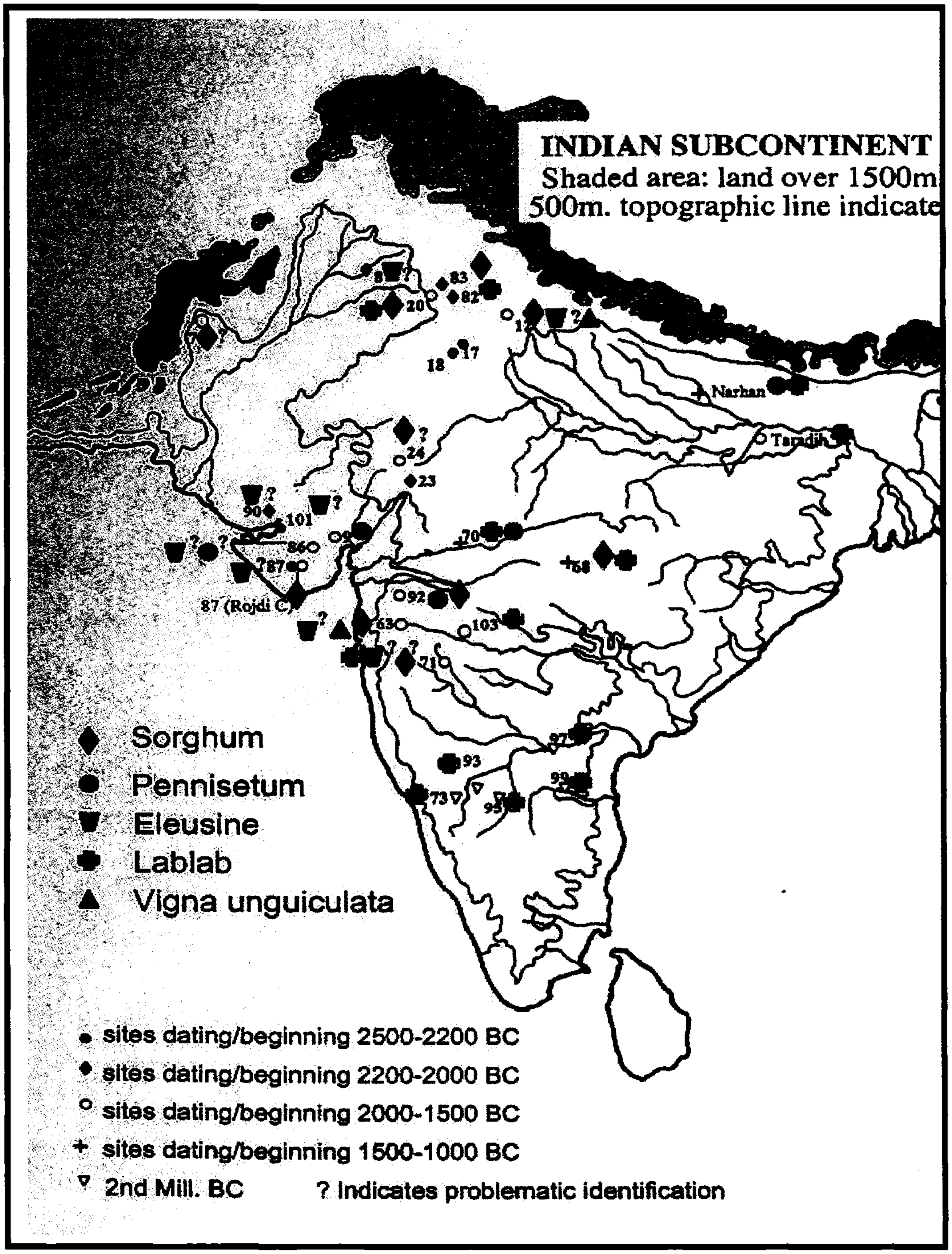


Figure 5.2: Map Showing Archaeological Distribution of African Millets in India (After Fuller 2002, pp.311, Figure 4)

modified. Most of the scholars now agree on three regions: the North-West or the Indus valley Vindhayan region (including the Ganga-Belan valley), and Southern India and more recently Western Rajathan/Mewar Region.

Although it has been suggested by most of the scholars working in the subcontinent that agriculture spread to South Asia through the Indus Valley region with spread of cultivated crops like wheat and barley from Southwest Asia through colonization and diffusion (Meadow 1996, 1998) (Figure 5.3). The extent to which the Indus region or the others of these Neolithic zones represents either the independent development of cultivation or the spread of agriculture from elsewhere by migration or diffusion, remains to be determined. A major problem facing Indian archaeologists interested in the agricultural origins is the early Holocene gap in the archaeological record (Fuller 2002). While microliths in the Mesolithic cultures are proposed to fill the gap, there are only few well-excavated sites that have been sampled accurately for the micro-botanical remains or accurately dated (Fuller 2002). However with the recent excavations at the Mesolithic sites of Bagor and the new AMS dates from the site, it can be proposed that this site can fill in this gap securely. This research study also clearly suggests (in accordance with Fuller 2002; Mehra 1997; Vishnu-Mitte 1989) that some of the native taxa (as mentioned above) may have been utilized before the introduction of domesticated crops like wheat and barley in the Mewar region of Rajasthan.

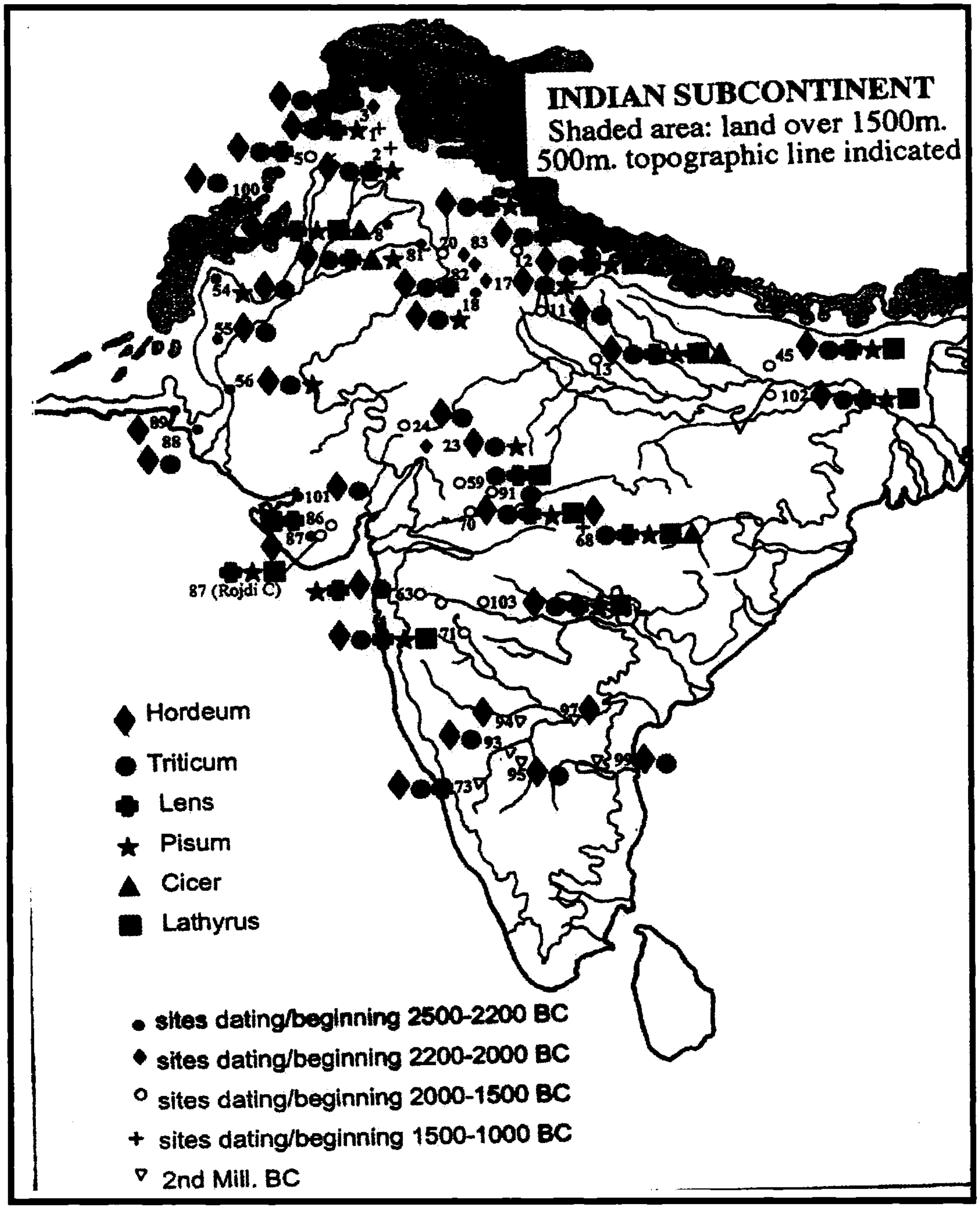


Figure 5.3: Map Showing Archaeological Distribution of Southwest Asian Crops in India (After Fuller 2002, pp.308, Figure 3)

Significance of the Present Research

The significance of this research is manifold. **First**, it has provided an opportunity to explore the subsistence activities occurring during the Mesolithic phase from a new perspective using forms of analyses (e.g., starch-grain analysis) unnoticed by the Indian archaeologists/archaeobotanists. Starch-grain analysis has provided the possibility of identifying with considerable accuracy specific plant foods such as vegetable (egg plant), fruits (date palm, mango), seeds (sesame), roots (ginger), and tubers (Cyperus) that were utilized in Indian prehistory, sadly missing in the Indian archaeological record. **Second**, the project has helped to develop a model for understanding the transition to food production in an important region of Indian subcontinent. Although a large number of Mesolithic sites have been recognized in Rajasthan, Northern Gujarat and Gangetic plains and south into the peninsular India and although these form part of a long tradition beginning in the early Holocene, few have been carefully excavated, dated or thoroughly studied (Possehl and Rissman 1992; Meadow 1996; Shinde *et al.* 2004) to securely document the transition from the hunting–gathering to food production. The reported archaeological evidence from these sites, although mostly preliminary, provides a picture of human existence intimately acquainted with wild plants and animal resources of the region. How the prehistoric people exploited these resources, and whether locally husbanded any of them remain questions not yet thoroughly investigated by Indian archaeologists working at the sites (Meadow 1996)? The results of starch-grain studies from Bagor suggest that agriculture on the Indian subcontinent may have included several levels of "man-plant relationships," from

acquaintance through exploitation to cultivation of indigenous seed crops (e.g., pulse, sesames), and possibly wild root crops (ginger, cyperus) which were subsequently transformed by the introduction of higher yielding crops like barley, introduced from South-West Asia and Finger millets and Sorghum from Africa. An important comparative case is that of North America (Piperno *et al.* 2000) where a large number, of small yield local crops, provided for the foundations of village life (which was subsequently transformed by the adoption of higher yielding crops like maize). With the systematic identification of starchy roots and tuberous crops, and the variety of seeds that were an important part of the hunter-gatherer diet at Bagor it can be proposed that their intensive exploitation might have led to the indigenous developments of small-scale cultivation systems during the Ceramic period at Bagor. This is also evident in the changes in stone-tool use at Bagor. The use-wear studies suggest that there is a substantive increase in the tools used for plant working activities including cutting and harvesting highly siliceous plants and cereals. This change is also reflected in changes in the other material culture at Bagor. Flimsy structures, few food-processing equipment from the Aceramic phase suggests that the Mesolithic people here had a semi-sedentary life, (according to the excavator they occupied the site for a considerably lengthy period but probably moved to another place for a certain period in their annual cycle). During the Ceramic period the structures represented by a patch of well-made floors, a large number of food processing equipments suggest a significant change to a more sedentary life at the site (Shinde: personal communication). The hunter-gatherers must have adopted more plants and gradually settled down to become the first farmers of Bagor.

CHAPTER 6

CONCLUSION

Introduction

New investigative techniques such as use-wear analysis and starch-grain studies can now penetrate the economic life of the prehistoric people and shed light on the processes that contributed to the changes in subsistence from the hunting-gathering to the agricultural stage of human development. This research is the first multidisciplinary project to apply these techniques to gain a deeper understanding of the economic transition at the site of Bagor in Rajasthan, India. Understanding this transition is a problem of major significance in India as it lies at the historical roots of the processes by which modern agriculture-based village life came about in the subcontinent (Korrisettar, Venkatasubbaiah and Fuller 2001). At present, however, there is very limited understanding of the primary mechanisms underlying this fundamental economic transition.

Most scholars working in India believe that the domestication of plants and animals spread to major parts of Western India from sites like Mehrgarh located near Bolan Pass in the Baluchistan region of Pakistan (Shinde 2002, Shinde *et al.* 2004). The site of Mehrgarh has produced interesting evidence in respect to the development and transition from hunting-gathering to food production (Shinde *et al.* 2004). Agriculture was dominated by domesticates like wheat and barley from Southwest Asia (Meadow 1996, 1998) and spread to the rest of India from there. With a closer investigation of the

Mewar region of Rajasthan, new evidence offers a contrary perspective: the transition may be indigenous (Shinde *et al.* 2004). The evidence in this respect is best documented at the site of Bagor.

The site of Bagor is located in the Bhilwara district of Rajasthan, India, and there archaeologists (Shinde *et. al* 2004) have recently excavated deposits of a Mesolithic period in a well-defined archaeological context. During this period, a culture based on hunting-gathering (*Aceramic*, cal. years 5700–4500 B.C.) underwent a gradual and continuous evolution and developed into a food-producing economy (*Ceramic*, cal. years 4500–3500 B. C) (Shinde *et al.* 2004).

The lower 25 cm of the habitational Layer 3 at the site constitutes the *Aceramic* of the Mesolithic. This phase represents the site's hunter-gatherer occupation. This phase dated to cal. years 5,700 B. C. (by AMS dates), has yielded a large number of microlith tools (made of chert and quartz), rubber stones and bone fragments. This phase also represents the earliest structures found at the site. Two dwelling structures were also identified in this phase. Both appear to be circular in shape with stone alignments in the periphery. Inside one of the structures, there is evidence for manufacturing tools and food processing. Tool manufacturing evidence comes from a considerably large core of quartz with debitage around it (Shinde *et al.* 2004). Nearby was found two heavily used rubber stones made of fine-grained sandstone and charred animal remains (Shinde *et al.* 2004).

The *Ceramic* is confined to layer 2 at the site. This phase, dated to around cal. years 4,500 B. C. (by AMS dates), provides the evidence of the continuation of the geometric microlithic industry and the structural activity without any drastic change with

the exception of a large amount of potsherds (Shinde 2004). This is the earliest evidence of potsherds in this region (Shinde *et al.* 2004). According to the excavator (Shine: personal communication) this phase belongs to the earliest farmers of the site.

In spite of its tremendous potentials, however, the site of Bagor still has not been thoroughly studied. The transition was proposed on the basis of the change from no Ceramic or potsherds present during the Aceramic Mesolithic phase to the introduction of potsherds during the Ceramic Mesolithic phase at the site. The study of animal remains and stone tools remains continues to be haphazard and the results still need to be integrated into a broader archaeological picture. Plant remains have been collected but are yet to be analyzed. To solve these problems and understand the transition this research took a multidisciplinary approach.

Significant Goals of the Research

The significant goals of this research were: **First,** to understand the subsistence and economic activities at Bagor by comparing the patterns of tool use between hunter–gatherers and food producers using use-wear analysis. Use-wear analysis also helped to determine the relation between tool techno-morphology and tool use, i.e. how the stone tools were actually put to use by the prehistoric settlers and what materials they were used on, thereby establishing their actual, purposes versus their proposed purposes. **Second**, to determine what kinds of plants were exploited by the hunter-gatherers and food-producers at the Bagor site using starch-gain analysis. **Finally**, to determine

whether plant residue analysis such as starch-grain analysis does complement and/or augment empirical data derived from use-wear analysis.

Research Questions and Analysis

Two sets of research questions were addressed in the dissertation:

The first set of questions relate to the activities of the prehistoric settlers at Bagor.

A. **What were the subsistence and economic activities carried out by the hunter-gatherers at Bagor? OR, what kinds of activities were performed with the tools by the hunter-gatherers?**

B. **What were the subsistence and economic activities of the farmers at Bagor? Did the utility of the tools change with the change to food production?**

Earlier it was not possible to answer some of these specific questions with great degrees of precision and accuracy. With the advent of microwear techniques (using light microscope and SEM coupled with EDS), it is possible to directly infer tool use from the microscopic traces of the wear left on their working edges.

Both these methods (light microscopy and SEM) were used to analyze the function of stone tools. Combined they provide an extremely powerful methodology. Use-wear analysis has become an important analytical technique since its introduction in modern archaeology by Semenov (See Chapter 2: pp. 32). In general it is the microscopic examination of the surface wears and fracture scars that form along the

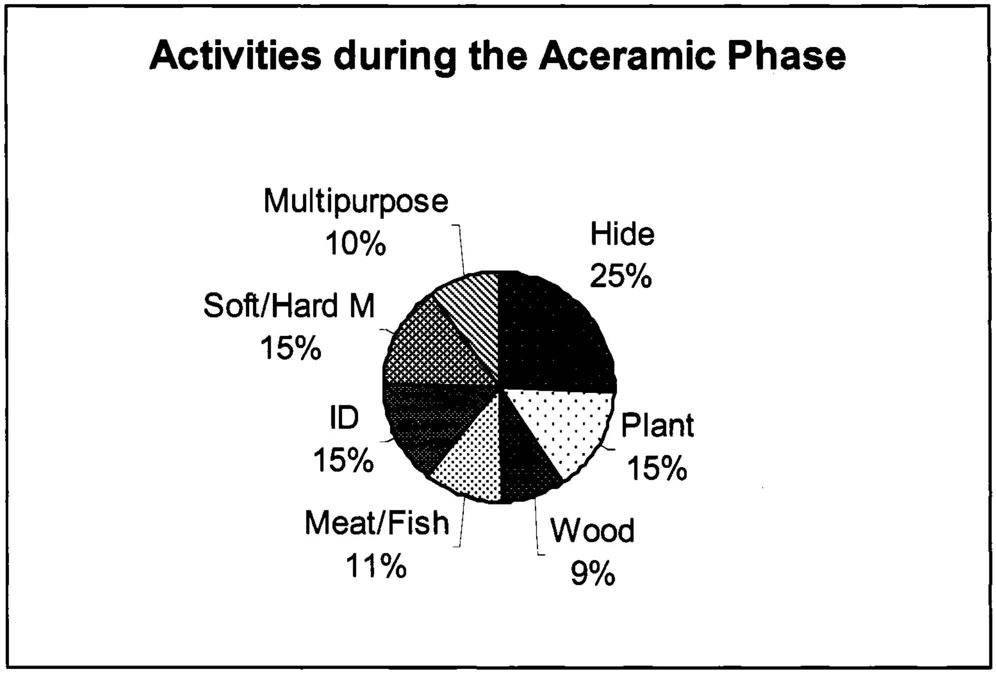
edges of the stone tools. Research has indicated that different kinds of wear fractures, scars, striations and polishes are produced on stone tools by the different kinds of materials being worked (like hide, meat, wild plants, domesticated cereals) and the different ways these materials are worked such as cutting, scraping, harvesting, sawing, etc. Experimentation has already led to the development of an attribute trait list for each kind of use. Although many of the characteristic polishes and striations are now understood, several use-wear analysts have also become aware of the fact that identification and origin of the use-wear can at times be ambiguous (Brose 1975; Levi Sala 1986). Furthermore, a wide range of post-depositional phenomena such as abrasion by the soil or the acid or alkaline nature of the soil may often hide or alter the wear traces and make functional analysis impossible (See Chapter 2 for details). The different degrees of freshness of the worked material, the amount of water in it, the time the tool was used, the raw material of the tool (e.g., quartz is considered unsuitable for use-wear studies due to its irregular surface texture, high reflectivity and hardness) and abrasives play important roles in the formation of the microwear polishes and striations (Anderson 1980; Brose 1975; Mansur 1975). Moreover, tests have revealed that some activities generate polish formations that are not very well developed (Brothwell 1965). Here SEM and EDS can help.

Conventional light microscope uses a series of glass lenses to bend light waves and create a magnified image. SEM creates the magnified image by using electrons rather than light waves. Thus at the same magnification level, the diagnostic potential of SEM is much greater than that of the light microscope (See Chapter 3 for details). These two features provide a great advantage to SEM and make

it possible to define the wear features and surface textural differences more accurately (even for tools made on quartz). Another advantage of SEM is the ability to apply X-Ray analysis with the help of EDS. EDS uses physico-chemical characterization to identify the residue on the stone tools (See Chapter 3 for details). Together light microscopy and SEM and EDS significantly enhanced the present research potentials.

Light microscopy was employed to study the microlithic stone tools (300 microliths in total were studied) used by hunter-gatherers (Aceramic phase) and food producers (Ceramic phase) at the site (See Appendix C and D). The results are fascinating and instructive. The use-wear analysis (prior to the archaeological study, controlled experiments were done and these experiments-sample tools were used as comparative material – See Appendix B) of the tools from Bagor has given us important insights into the subsistence and economic activities of the hunter-gatherers and farmers at the site (See Chapter 4 for details, Figure 6.1). The study shows that various activities such as hide work (25% of used tools); meat and fish processing (11% of used tools), wood work (9% of used tools), plant cutting (15% of used tools) and hunting (15% of the used tools) were carried out at the site during the Aceramic Mesolithic (Figure 6.1).

There is continuity as well as changes in the activities carried out at the site during the Ceramic Phase at Bagor. The prehistoric people still participated in activities such as hide work (18% of used tools studied), meat and fish processing (11% of used tools studied), hunting (6% of the used tools studied), and wood work (17% of used tools studied). Yet there is also a substantial increase in plant cutting activities (36% of the



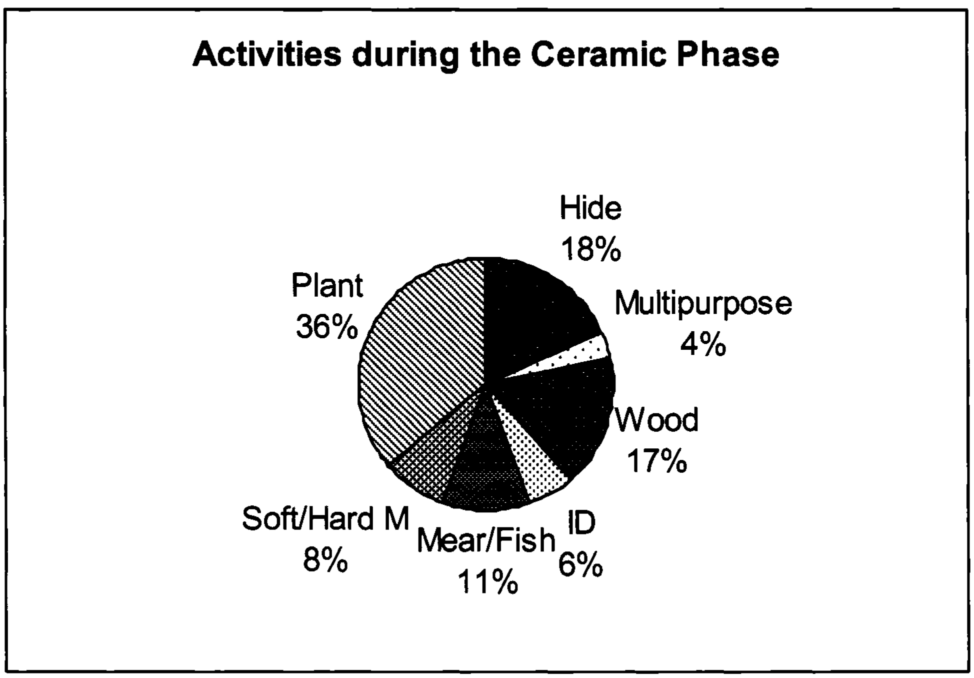


Figure 6.1: Comparison of Activities during the Aceramic and Ceramic Phase

used tools) studied suggests a significant change in the subsistence activities during the Ceramic phase (Figure 6.1).

On some of the tools (e.g., 12 tools from the Aceramic phase) only the hardness of the material was determined. In order to determine the use of the tools they were further studied under SEM[1]. They were examined under the SEM to observe the changes in their surface texture and micro-topography that are not discernible under light microscope. Five tools used on soft animals seem to have been used for scraping hide (See Chapter 4 for details). Three points labeled as used on hard plant material from the Aceramic phase were also studied under SEM. SEM analysis shows that these points were used for drilling wood (See Chapter 4 for details). Drilling wood makes very distinct changes in the micro-topography. Surface cracks and linear feature striations were observed on the tip of the point used for drilling wood.

SEM and EDS were also used to study the metallic residue found on the edges of three microliths from Bagor (See Chapter 3). These tool edges provide visual evidence of what seems to be copper metal when studied under magnification of 400X under light microscope. EDS analysis of the tools suggests that the residue was indeed copper (Kashyap and Shinde 2005). This is a very significant discovery as it throws new light on the blade production technique at Bagor. M. L. Inizan and M. Lechevallier (1995), who studied the technology at Bagor after the 1968–1970 excavation, have suggested that the pressure debitage technique was fully mastered by the Mesolithic people at the site. The SEM and EDS analysis suggests that they belong to a certain stage of this technical

[1] It must be kept in mind that both SEM and EDS are very expensive and time-consuming therefore, only a very limited number of tools were studied under SEM and EDS. Also only a few tools from the Aceramic phase which the author could bring to the U.S. were studied under SEM. Since the other tools were analyzed in India they could not be analyzed under SEM.

tradition, when metal (in this case copper) was introduced in pressure debitage. This study shows that used together with light microscope, SEM can prove to be a very powerful methodology for understanding not only the primary economic activities of the prehistoric inhabitants but their stone-tool making technology.

Use-wear analysis also helped to determine the relationship between tool techno-morphology and tool use at Bagor (See Chapter 2 for details). On the basis of the techno-morphology the excavators have classified the stone tools at Bagor and proposed a particular function for them (See Chapter 4, Tables 4.5 and 4.10) but it is significant to know whether tools were used for the proposed functions by the inhabitants at Bagor. The difference between tool function and tool use can have significant behavioral implications. Consider the following contemporary examples of the distinction between tools function and use. A screwdriver, for example is a tool designed to turn screws, yet a screwdriver can be used for other functions as well, for which the tool was not designed–such as to open paint cans or make holes. The correct use analysis of screwdrivers would indicate its actual use as opposed to its intended use. This may be true for the microliths from Bagor as well. Moreover, we might be using absolutely wrong criteria to classify tools at Bagor. It is in making these distinctions that use-wear techniques become indispensable. The analysis from this new technology sheds light on the real use — how the stone tools were actually put to use by the hunter-gatherers and farmers at Bagor, and what materials they were used on, establishing their actual (as opposed to presumed) purposes.

The present use-wear studies have revealed a very mixed relationship between tool techno-morphology and tool use at the site of Bagor[2]. Five types of microliths were examined from the Aceramic phase for this study (See Chapter 4 for details). Table 4.5 shows their presumed function on the basis of techno-morphology and their actual use by the hunter-gatherers at Bagor.

A retouched blade's function as hypothesized by the excavators (n= 53), for example, is that of a knife for butchering animals, cutting plants and wood, etc. The use-wear studies show that–although blades were used as knives for cutting and longitudinal (n=13) activities by the hunter-gatherers (Aceramic phase) – a few were also used as scrapers for scraping. Some were used for transverse activities like whittling (n = 16), and some were used for multipurpose such as both scraping and cutting (n= 2).

Both points (n=37) and triangles (n=17) are hypothesized by the excavators to have been used as barbs in arrows to hunt animals. Although all of the used triangles (n= 8) from the Aceramic phase have impact traces resembling a projectile, the points are used both for hunting purposes (n= 4) and others activities (n= 14) like piercing, drilling and puncturing hide and wood.

The scrapers (n = 13) were put to use for scraping (n= 3), and cutting and butchering (n = 3). For the unretouched tools it is usually proposed that they are used on a need basis. At Bagor this has proved to be true. The microliths studied show that they

[2] It is important to note that the following observations are made on the basis of the 300 tools studied for this site. More tools need to be studied before anything can be definitely said about this problem as a whole for Indian Archaeology.

are used for a wide range of purposes. Thus we see that the relationship between form and function relationship does not hold well in all cases during the Aceramic phase.

For the Ceramic phase six types of microlithic tools were analyzed (See Chapter 4 for details). Table 4.10 (Chapter 4) shows their presumed function on the basis of techno-morphology and of by the farmers at Bagor. The results are informative concerning the relationship between techno-morphological types and their usage. Points and triangles (n= 10, n= 5) are hypothesized by the excavators to have been used as barbs in arrows to hunt animals. All the used triangles have impact traces resembling a projectile. The points have impact damage both from being used as projectiles and used for different activities like piercing, drilling and puncturing hide and wood. For the unretouched (n = 28) tools it is usually proposed that they are used on a need basis. At Bagor this proved to be true. The microliths studied show that they are used for wide range of purposes (See Chapter 4 and Tables 4.8 and 4.9). Retouched Flakes (n= 11) were also used for multi purpose activities.

During the Ceramic phase (as is evident from Table 4.9 – Chapter 4) retouched blades (24 of the 31 retouched blades were used for cutting plants and whittling wood) were being used for cutting purposes (n=12) rather than scraping purposes (n=4) or whittling purpose (n=7). One interesting artifact studied for this research is crescents (n=29); they were found only in the samples from the Ceramic phase[3]. Neither excavators (Shinde or Misra) have however proposed a particular function for this tool. According to L. H. Robbins (L. H. Robbins, Department of Anthropology, Michigan State University: Personal Communication) crescents were widespread in Africa during

[3] It must be noted that this could be a sampling error as the tools studied for this research were provided by the excavator.

the Late Stone Age. The most prevalent interpretation according to African archaeologists is that they were used as projectile insets in the shafts of arrows. This introduces an important comparison – almost all crescents studied for use-wear from Bagor were used for harvesting and cutting plants (See Chapter 4, Tables 4.8 and 4.9; Also see Table 6.1). It could be argued that the findings about crescents have only regional implications and therefore the comparison is specious. Scrapers (n=2) have been used for scraping purposes only during the Ceramic phase (Table 4.8) as opposed to both scraping and cutting purposes during the Aceramic phase. On the basis of the above observations it might be proposed that there was a change in the utility of some of the tool (especially retouched blades and scrapers) with the change in subsistence from hunting-gathering to food production. During the Ceramic phase more tools were being utilized for plant working activities than in the Aceramic phase.

Though use-wear analysis disclose that different kinds of plant materials were being processed by the prehistoric settlers at the site, it failed to provide information about the specific kinds of plants being used by the hunter-gatherers and food producers at the site. This brings us to the second important goal of this research and the second set of research questions addressed in this dissertation.

The second sets of questions concerned the determination of the kinds of plants exploited by prehistoric settlers.

A. **What kinds of plants did the hunter-gatherers exploit?**

B. **What kinds of plants did the earliest farmers at the site use?**

To reconstruct the plant food processed at the site starch-grain analysis was integrated into the use-wear research. Starch-grain studies complemented the

information about the kinds of plants and cultigens utilized by the hunter-gatherers (Aceramic phase) and the farmers (Ceramic phase). Starch-grain analysis was conducted on the 15 microlithic tools (2 grinders) and 3 soil samples from the Mesolithic phase (See Appendix G and H). It has provided a very good understanding of the kinds of plants exploited by the hunter-gatherers and food producers at Bagor.

Starch-grain studies show that Aceramic inhabitants were subsisting on a mixed economy. They exploited root crops possibly *Zingiber* (Ginger) and *Cyperus*, vegetables possibly *Solanaum* (Eggplant), grasses like *Sesamum* (Sesame), beans/pulses like *Macrotyloma* (Horse gram) and fruits possibly *Phoenix* (Date Palm) and *Mangifera* (Mango).

New plants are added to the economy during the Ceramic phase: including fruits possibly *Tamarindus* (Tamarind), *Phoenix* (Date Palm) and *Mangifera* (Mango). Beans/pulses like *Vigna* species and possibly *Cajanus* (Pigeon peas) are added to the list with *Macrotyloma* (Horse gram). Although more research with both introduced and local millets in India needs to be done before anything can be securely said about the finds of millets, there is evidence of the introduction of new species probably domesticated in Africa including possibly *Eleusine* (Finger Millets) and *Sorghum* (Jowar) at Bagor during the Ceramic phase. Also interesting is the starch grain: possibly *Hordeum* (Barley) on the grinder studied from the Ceramic phase at Bagor. Starch-grain studies provide evidence of intensification of plant use during the Ceramic phase.

Another significant goal of this research was to determine whether plant-residue analysis such as starch grain analysis complements use-wear studies. After the residue was extracted from the microliths for starch-grain analysis, the microliths were cleaned

and studied for the use-wear to see if the use-wear studies were consistent with the starch-grain studies done at the site (Table 6.1) and whether they complement each other. The results are fascinating. Of the 15 microlithic tools studied only 7 of them have use-wear traces. The starch-grain analysis suggests that all of these tools were used on various kinds of plants; this is consistent with the use-wear results. In the case of the 7 tools with no use-wear on them (Sample no. 1, 3, 2, 9, 14, 11 and 17), the starch-grain analysis complements the use-wear results. As mentioned before (Chapter 4 and Appendix B) use-wear from some plants (e.g., roots and tubers, soft vegetables and other non-siliceous plants) is very difficult to develop. They develop only after prolonged use and only in the presence of other factors such as water, dirt and grit. The starch-grain study of the above mentioned tools (with no use-wear traces) reveals starches from soft plants, vegetables and fruits (Table 6.1) but no use-wear is present on them. This indicates that although the tools were used on such plant materials they were probably not used for a long duration or other external factors (dirt or grit) were not present to incur use-wear. This is a very important finding: it signifies that plant-residue studies such as starch-grain analysis can complement use-wear studies. This is a very significant contribution to the archaeological assessment of prehistoric peoples. Why? Because soft plants and roots and tuber, absent from the archeological records, cannot be ruled out as an important subsistence and economic activity at prehistoric sites.

On the basis of this study it can be proposed that a combination of use-wear analysis and starch-grain studies can provide a more reliable reconstruction of the economic and subsistence activities at prehistoric sites than can either method alone. This is true, moreover, in both hunter-gatherer and food-producing contexts at Bagor.

TABLE 6.1: SUMMARY OF MICROWEAR AND STARCH-GRAIN ANALYSIS

Sample No.	Mesolithic Phase	Tool Type	Use-wear	Total Starch	Type of Starches
1	Aceramic (5600 – 4490 B. C.)	Retouched Blade	No	4	cf. *Cyperus* = 1 cf. *Solanum* (Egg plant) seed starch = 3
6	Aceramic (5600 – 4490 B. C.)	Unretouched Blade	Yes Roots and Tubers	5	Unknown Damaged Starch = 3 Compound Starch = 2
7	Aceramic (5600 – 4490 B. C.)	Unretouched Flake	No	X	X
9	Aceramic (5600 – 4490 B. C.)	Retouched Blade	No	2	cf. *Mangifera* - 1 Compound Starch – 1
10	Aceramic (5600 – 4490 B. C.)	Crescent	Yes Siliceous Plant	5	Compound Starch = 3 Unknown Bean Starch = 1 Unknown Starch = 1
11	Aceramic (5600 – 4490 B. C.)	Unretouched Blade	No	2	Unknown Starch =1 Damaged Starch consistent with Bean = 1
13	Aceramic (5600 – 4490 B. C.)	Unretouched Blade	Yes Siliceous Plant	4	Compound Starch = 3 cf. *Solanum* (Egg plant) pericarp starch (Eggplant) = 1
16	Aceramic (5600 – 4490 B. C.)	Grinder	Broken (only one half could be recovered)- looks intensely used	17	Unknown Starch = 1 Compound Starch = 1 cf. *Solanum* (Egg plant) = 1 cf. *Zingiber* (Ginger) = 1 cf. *Macrotyloma* (Horse gram) = 1 cf. *Sesamum* (Sesame) = 10 *Mangifera* (Mango) = 2

TABLE 6.1 (CONTD.): SUMMARY OF MICROWEAR AND STARCH-GRAIN ANALYSIS

Sample No.	Mesolithic Phase	Tool Type	Use-wear	Total Starch	Type of Starches
2	Ceramic (4490 – 3500 B. C.)	Retouched Blade	No	6	Unknown Damaged Starch = 3, Damaged Starch cf. *Solanum* (Egg plant) seed starch = 1 Unknown Starch = 1 cf. *Tamarindus* (Tamarind) =1
3	Ceramic (4490 – 3500 B. C.)	Unretouched Flake	No	8	Unknown Damaged Starch = 3, Compound Starch = 2 Unknown Starch = 3
5	Ceramic (4490 – 3500 B. C.)	Crescent	Yes Soft Plant	9	Unknown Damaged Starch = 3, Compound Starch = 2 Unknown Starch = 3 cf. *Solanum* (Egg Plant) = 1
8	Ceramic (4490 – 3500 B. C.)	Retouched Blade	Yes Roots and Tubers	5	Unknown Damaged = 2 cf. *Zingiber* (Ginger) = 1 cf. *Solanum* (Egg plant) = 1 pericarp Compound grain = 1
12	Ceramic (4490 – 3500 B. C.)	Crescent	Yes Soft Plant	8	Unknown Bean Starch = 1 Starch Granules =1 cf. *Vigna* sp. = 1 cf. Macrotyloma (Horse Gram) =1 Compound Starch = 3 Damaged Starch = 1

TABLE 6.1 (CONTD.): SUMMARY OF MICROWEAR AND STARCH-GRAIN ANALYSIS

Sample No.	Mesolithic Phase	Tool Type	Use-wear	Total Starch	Type of Starches
14	Ceramic (4490 – 3500 B. C.)	Retouched Blade	No	10	cf. *Mangifera* = 2 cf. *Solanum* (Egg Plant) = 4 (1 seed and 3 pericarp) Damaged Starch = 1 Unknown Starch = 3
15	Ceramic (4490 – 3500 B. C.)	Retouched Blade	Yes Siliceous Plant	50	Compound Starch = 25 cf. *Cajanus* (Pigeon Pea) = 2 *Macrotyloma* (Horse gram) = 2 Damaged Bean Starch = 2 cf. *Phoenix* (Date Palm) = 2 cf. *Tamarindus* (Tamarind) = 2 Unknown Starch = 4 cf. *Eleusine* (Finger millet) =1 cf. *Sesamum* (Sesame) = 7 Unknown Damaged Starch = 1 Damaged Starch = 1 cf. Sorghum = 1
17	Ceramic (4490 – 3500 B. C.)	Unretouched Blade	No	5	Compound Starch = 2 Unidentified Starch = 1 Damaged Starch = 2

TABLE 6.1 (CONTD.): SUMMARY OF MICROWEAR AND STARCH-GRAIN ANALYSIS

Sample No.	Mesolithic Phase	Tool Type	Use-wear	Total Starch	Type of Starches
26	Ceramic	Grinder	Fully intact (heavily used)	86	Unknown Damaged Starch = 1 cf. *Mangifera* (Mango) = 7 cf. *Phoenix* (Date Palm) =1 Unknown Starch = 1 cf. *Solanum* (Egg Plant) seed starch = 70 cf. *Solanum* (Egg Plant) pericarp starch = 6 cf. *Eleusine* (Finger Millet) cf. *Hordeum* (Barley) = 1

Along with this study a fully detailed investigation of the fauna and the botanical remains (when published in the future) will provide the major information on subsistence patterns at the site. When that is done archaeologists and archaeobotanists will be in a position to evaluate whether the primary macro subsistence data (bones and plants) are in agreement with the results of the present use-wear and starch-grain finds or whether these microscopic studies reveal a more detailed record that is missing in the standard macro studies. The future macro-botanical and faunal studies would make it possible to compare the results of the microscope-based data revealed in this study, providing multiple lines of evidence to understand the life of the prehistoric people at Bagor.

Significance of the Research: Contributions to Indian Archaeology

The contribution of this research to Indian archaeology is manifold. This dissertation research has provided an opportunity to explore the economic and subsistence activities occurring in the transition from hunting-gathering to food production in an important region in India from a new perspective. What we have currently for India, in particular, and South Asia, in general, is a patchy archaeological framework with little depth and understanding of any single region, let alone for an entire area. Eventually, understanding this process requires an intensive survey and the excavation of many sites in regions throughout India. While this goes beyond the scope of a single project, this research–with the help of use-wear and starch-grain analysis -- establishes a necessary phase in the process of information gathering pertinent to this significant human transition in India.

Together use-wear and starch-grain analysis provide a more reliable reconstruction of the subsistence and economic activities at Bagor. Use-wear analysis shows that there is both continuity and change in the subsistence activities at Bagor. Although activities such as hunting, meat and fish processing continue at the site there is a substantial increase in the plant processing activities during the Ceramic phase (See Chapter 4 for details) that suggests the beginning of incipient agriculture during the Ceramic phase.

This is also reflected in the starch-grain data. It shows intensification of plant use during the Ceramic phase. Plants -- such as possibly *Tamarindus*, *Phoenix*, *Mangifera*, *Cajanus* and *Vigna* species, barley and millets such as *Eleusine* (??) and *Sorghum* (?) are added to the list of others exploited by the Aceramic phase people (See Chapter 5 for details). The presence of plants such as barley during the Ceramic phase is also a very significant finding because this indicates agriculture on the Indian subcontinent included several levels of "man-plant relationship" (putting into question the idea that the spread was primarily due to colonization). It can be proposed early food production in India began with the intensified gathering, followed by cultivation of indigenous seed (e.g., *Sesamum* and *Macrotyloma*), and root crops (e.g., *Zingiber*) and it was subsequently transformed by the introduction of higher yielding crops like wheat and barley, introduced from Southwest Asia.

The present research also helps to clarify the understanding of the term Mesolithic in Bagor context. The Mesolithic has traditionally been seen as the period of small bands of nomadic wanderers, who subsisted on hunting and foraging and lacked evidence of food production. According to Possehl and Rissman (1992) the term Mesolithic is a

much-abused concept in Indian archaeology. They point out that in India "Mesolithic people made proper microliths . . . But it also true in India that many people who ought not to be called Mesolithic made such tools (here they refer to the prehistoric settlers of what they call Early Food Producing sites like Koldihwa, Bagor and Adamgarh caves). There is no necessary correlation between these tools and a particular form of settlement and subsistence. (1992, pp. 469, also see pp. 473-467)." Confusion over the definition of the Mesolithic settlement and subsistence versus tool typology has muddled much of the writings in Indian archaeology. Some archaeologists have defined Mesolithic on the basis of subsistence and settlement patterns of the prehistoric people (e.g., Sussman *et al.* 1983). Others like Misra (2001), Shinde (2002, Shinde *et al.* 2004) imply that if a tool assemblage contains microlith it is thereby Mesolithic by definition basing the term Mesolithic strictly on tool typology.

Although there is evidence of food production at Bagor, the site is still considered Mesolithic by its excavators because prehistoric settlers here made microlithic tools–blades, crescents, triangles, points, etc. However with the new evidence of the use of copper metal and incipient agriculture, the important question is this: what terminology should be used for Bagor? Should it still be called a Mesolithic site only because the prehistoric settlers used microlithic tools for subsistence? Or, an early food producing site in so far as it has incipient agriculture and is in gradual transition to Chalcolithic? To answer this question lets examine the data again.

It has been proposed that improved climatic conditions (around 10,000 years ago) and abundance of plants and animal food in the semi-arid region of Western India led to an explosion of hunter-gatherer populations here (Misra and Rajguru 1989; Shinde *et al.*

2004). Changing environment around the middle of the Holocene, population pressure and depleting resources, however, all forced these hunter-gatherer groups to settle in congenial environments that had better resources, such as water and plant (provided opportunities for selecting local cultigens) and animal life (Shinde 2002; Shinde *et al.* 2004).

Bagor attracted the attention of the hunter-gatherers because of several factors (Shinde *et al.* 2004) --

(1) The site is located near arable pastureland, ideal pastoral livelihood (See Chapter 3, Figure 3.3).

(2) There are a large number of rocky outcrops of quartz (See Chapter 3, Figure 3.5), which might have provided the hunter-gatherers with suitable raw material required for the manufacture of their tools and equipment and for the maintenance of day-to-day life.

(3) The ecological conditions around the site are ideal for agriculture (See Chapter 3, Figure 3.2). Shinde *et al.* 2004 have proposed that the area around Bagor "provided . . . hunter-gatherer population with wild cultigens of cultivable grass which they collected and utilized for their food requirements." The foragers at Bagor must have "slowly observed the seasonal changes and innovated the process of incipient agriculture … and domesticated some of the wild cultigens of the region and settled in the region (392)."

Use-wear and starch-grain analysis done for this research also suggests a similar shift in subsistence at the site. As mentioned above during the Aceramic phase a number of seed and root and tuber crops were exploited by the hunter-gatherers. By the Ceramic

phase we have evidence that additional plants were incorporated into the eating habits of the prehistoric settlers at the site (See Chapter 5 for details). What we have at Bagor is thus an uninterrupted story of a continuous sequence of transition from the stage of intensified food-gathering and hunting during the Aceramic phase to incipient food production during the Ceramic phase[4]. On the basis of the data on the increase in the plant processing activities and intensification of plant exploitation and the use of copper metal for making microlithic tools at the site, I would argue along with Possehl and Rissman (1992: 469) that to call Bagor a Mesolithic site just because of the fact that people here made microliths has little or no utility. With the new evidence from this research this site should be called an Early Food Producing site and not a Mesolithic site.

Broader Contributions of this Research

The anthropological significance of this research is manifold. It is an important part of the long-term study of prehistoric economic behavior that has fascinated anthropologists. **First**, the data from the site will allow comparisons to better understand better the similarities and differences of processes of adaptation to domestication in different areas of the world.

Second, it will assist us to determine better the structural changes in the way of life of prehistoric peoples in their adaptation to agriculture, and how those changes might correlate with other variables such as habitat change and population dynamics. This new

[4] More research needs to be done before we can say if the plant remains at the site were wild or domesticated.

information will contribute to theoretical approaches by providing more specific data than currently exists, making it possible to test new hypotheses concerning the transition to food production.

Finally, this research will also be a methodological contribution insofar as it allows for the examination of the merits of several different analytical approaches. Although use-wear analysis has been used to reconstruct the primary economic and subsistence activities of the prehistoric people in different parts of the world, very little innovative research of this type has been done in India. Few works that were done in the late 1970s and early 1980s are not well documented (Pant 1979, Sinha 1985). Plant-residue studies are still in their infancy in India. The combined use of these techniques to address this problem has not been done in India. This study, therefore, has long-range implications for advancing archeological knowledge, not only in anthropological theory (i.e., archaeology as part of history as opposed to anthropology per se), but also for advancing the scientific method in archaeological research (e.g., the use-wear and plant-residue analysis), that the Indian archaeologists need to incorporate in the discipline.

Future Direction

While this study has contributed to a preliminary understanding of the transition at the Bagor site, much more needs to be done. **First,** another large-scale excavation of the site is needed. This will help us to compare the ways of life of the hunter-gatherers and farmers at Bagor on a much broader scale– especially concerning answers about how

housing, settlement pattern, and regional interaction, among others changed during the transition to food production.

Second, animal remains have to be studied thoroughly (to understand when the prehistoric settlers started domesticating animals) and integrate those studies with the plant and stone tool study.

Third, to properly understand this process requires an intensive survey and excavation of many sites in regions throughout India. While this goes beyond the scope of a single project, the proposed research will provide hopefully a model for further studies.

Fourth, the starch-grain analysis done for this dissertation has yielded excellent results, but a lot more needs to be done here as well. The modern reference collection needs to be expanded, especially in regards to millets in India. One of the most heated debates among Indian archaeobotanists concerns the diffusion and spread of millets in India (See Chapter 5). A comparative study of millets will enable researchers to provide answers to this question. Also, as mentioned before, more ground work needs to be done in collecting wild species of the plants found at Bagor; they need to be studied in the lab before it can be said whether the plants found at the site are crop plants or near-wild relatives of the crop.

Fifth, more tool types and a larger, and more representative sample of microliths need to be studied for use-wear analysis in the future so that we can not only properly understand the relationship between tool techno-morphology and tool use at the site of Bagor but we can also potentially eliminate the problem of sampling error.

Finally, SEM and EDS analysis of the microliths from Bagor allow us to infer the presence and use of metal at the site, in absence of any metallic remains. The use of metal brings forth some important questions: (1) Where did the Mesolithic people get the copper from? (2) Did they make copper tips at Bagor? (3) Were they familiar with smelting technology? If so, why don't we have any other evidence of copper at the site? Is it possible that copper was totally reused at Bagor or destroyed by soil agents completely? (4) Were they getting copper tips from others through trade? Scholars like Anderson *et al.* (1989) and Pelegrin (1994) among others have proposed that copper was being used in the blade manufacturing process as early as 5,600 B.C. at the Pre-Harappan sites. Did the prehistoric settlers at Bagor get the copper through long distance trade with the Harappans? All these questions need to be investigated in the future.

USE WEAR AND STARCH GRAIN ANALYSIS: AN INTEGRATED APPROACH TO UNDERSTANDING THE TRANSITION FROM HUNTING GATHERING TO FOOD PRODUCTION AT BAGOR, RAJASTHAN, INDIA

Volume II

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Anthropology

2006

APPENDIX A

VARIABLES AND CATEGORIES FOR USE WEAR STUDIES

This appendix contains a description of the variables and categories used for characterizing the use wear on the microlithic tools from Bagor.

LEVEL I

1. Site

2. Unit/ Provenance: The unit and provenance from which the microlithic tools were collected.

3. Artifact size: The size of the microlithic tools

1. Length

2. Width

3. Weight

4. Types: The techno-morphology of the microlithic tools studied from Bagor

1. Blade

2. Lunates

3. Burins

4. Crescent

5. Triangle

6. Scrapers

8. Unretouched Flakes

9. Unretouched Blades

5. Patina: It refers to the post-depositional surface modification on the tool seen through naked eyes.

1. Not Patinated

2. Lightly Patinated

3. Heavily Patinated

4. Unsure

6. Raw Material: Raw material used for the tool making

1. Chert

2. Quartz

LEVEL II

7. No. of PUA: It refers to the number of potentially utilized areas on the tool.

8. Location of the retouch: It refers to the area where retouch is located.

1. Ventral

2. Dorsal

3. Bifacial/Alternating

9. Distribution of the retouch: The spacing of the retouch on the tools.

1. Overlapping

2. Close Regular

3. Close Irregular

4. Not Applicable

10. Form of retouch: The morphology of the retouch scars.

1. Scalar

2. Half Moon

3. Other

4. Unsure

11. Fracture: The type of fracture scars.

1. Minute

2. Small

3. Medium

4. Large

5. Extremely Large

12. Fracture Termination

1. Feather

2. Step

3. Hinge

4. Snap

13. Degree of the wear: How much the tool edges are worn from the use?

1. Lightly Worn

2. Medium Worn

3. Heavily Worn

4. Probably Used

LEVEL III

14. No. of AUA: Number of Actually used Areas

15. Retouch Location

1. Ventral Only

2. Dorsal Only

3. Bifacial

16. Use Retouch Distribution

1. Overlapping

2. Close Regular

3. Close Irregular

4. Not Applicable

17. Polish Location: Location of the polish, and the relative extent.

1. Dorsal Only

2. Ventral Only

3. Dorsal + Ventral, but Dorsal More

4. Dorsal + Ventral, but Ventral More

18. Polish Texture: The texture of the Polish, this variable is related to contact material

1. Smooth

2. Smooth and Greasy

3. Smooth and Matt

4. Rough

5. Rough and Matt

6. Rough and Greasy

19. Polish Brightness: This variable is also related to the contact material

1. Bright

2. Very Bright

3. Dull

4. Not Applicable

20. Polish Topography

1. Doomed

2. Flat

3. Cratered

4. Pitted

5. Comet tail

6. Corrugated

21. Striations: Striaes on the tools due to contact, where they are located.

1. None

2. Very few

3. Common

4. Dense

23. Contact material inferred: The material the tool was used on.

1. Bone

2. Soft plant

3. Wood

4. Hide

5. Meat

6. Pottery

7. Fish

8. Soft material

9. Hard material

10. Bone-antler/ Bone-wood

11. Undetermined

24. Degree of certainty

1. Certain inference

2. Uncertain inference

APPENDIX B

THE CONTROLLED EXPERIMENTS

Use wear requires a substantial number of controlled experiments, where the investigator makes replicas of artifacts and tests them on a variety of uses of different worked materials in order to have a "control" sample to compare with prehistoric artifacts. Since little work of such kind has been done in India so far, 50 (Figures 1 – 4) experiments were performed to prepare a reference collection before proceeding with the study. Duration of work varied from five minutes to five hours. The activities included cutting, slicing, butchering, whittling, scraping and boring etc. The raw material (chert) used for the experimental pieces were provided by the excavator Vasant Shinde. The tools were knapped by the author and Dr. Shinde India. The results of most of the experiment are interesting and are consistent with the finds of Donahue 1986; Keeley (1980); Gijn (1989); Vaughan (1985).

All the experimental tools were immersed in an ultrasonic cleaning tank containing ammonia-free detergent solution (See Chapter 2 for details). Successive washes using clean water, was also done. Apart from initial cleaning, regular cleaning during examination is extremely essential. Alcohol was used during examination to remove finger-grease and grease from the clay supporting the tools. After the tools were studied micro-photographs were taken of the use wear on the experimental tools. All the photographs were taken at 400 X unless otherwise mentioned

Experiments 1 – 5: Working on Dry Hide Experiments (Figure 5)

In these set of experiments 5 microlithic tools (4 scrapers and 1 blade) are used for scraping, cutting and boring dry hide from fifteen minutes to one hour. Under microscopic examination (200 X and 400 X) the edges of the tools are moderate to heavily round, more rounded in the scraping tools than cutting or boring tools. The tools have very little edge removal. The retouch is scalar with deep initiations and a hinged or feathered termination. The polished surface is dull compared to the original surface. Polish texture varies from rough and greasy to rough and matt. Polish topography is cratered in most cases. The distribution of polish is in form of a band along the edge in all the scraping experiments. Cutting resulted in longitudinal streaks of polish.

Experiment 6: Working on Wet Hide

In this experiment a retouched blade tool is used to scrape fresh rabbit hide. The tool was used for one hour and fifteen minutes. It was then cleaned in soap water in an ultra sonic cleaner. This is not an easy experiment because the grease and the flesh made the tool very slippery to handle. By the end an hour the tool was very difficult to use and had become very dull (Brose 1975, Donahue 1986). After the experiment the tool was cleaned and studied under the microscope. The tool has very little edge rounding, the surface has a fluid appearance and is very, very greasy even after several washes. There are only few small fractures around the edge of the tool are seen. Other than the greasy and fluid look it is very difficult to distinguish the exact state of hide polish on the tools. This is in consistence with the observation made by Gijn (1989).

Experiment 7 - 10: Cutting Meat and Butchering (Figure 6)

In this experiment a retouched blade tool was used to cut strips of boneless chicken for forty five minutes. The tool was cleaned in soapy water in an ultrasonic cleaner. The tool displays a thin line of polish along the edge. The polish is bright and greasy looking. Other characteristics like texture, striations or topography could not be determined.

In butchering experiments 2 retouched blades were used to butcher rabbit for thirty minutes and 1 hour. The tools came in contact with bone several times. The tools were cleaned and studied under the microscope. The edge is rounded with fracture scars and a bright line of polish which appears rough and greasy. The tool has fracture scars (here a bright, polish with clear directionality is also noticed) from getting in contact with bone during butchering. There is edge scaring on the tool used for one hour.

Traces from meat processing have been a source of debate amongst the wear analysts (Keeley 1980; Vaughan 1985). For Keeley (1980) meat polish is pretty distinctive because it produces greasy luster with few striations. Vaughan (1985) and Anderson-Gerfuad (1981) have shown through experiments that meat causes generic weak polish and cannot be distinguished. The experiments conducted for the research did not produce well developed traces of meat processing without bone contact (See Appendix C). So meat cutting, butchering and skinning are kept under meat processing activities for this study.

Experiments 11 – 13: Fish Scraping and Cutting (Figure 7)

Three tools (two scrapers and one retouched blade) were used to scrape scales, cut and decapitate fish for thirty minutes each (hard sale and bony fish "*Hilsa spp.*" was used). The tools were then cleaned and observed under a microscope. Edge rounding is moderate on the tool scraper used for scraping fish scales. Use retouch is closely distributed. Polish on the tools are variable from very bright to bright. The texture is rough and corrugated. The tools used for cutting the fish displayed comet tails indistinguishable from the traces on tools used for bone cutting experiment. Closely associated linear streaks developed on the tool used for decapitating the fish.

Fish polish from cutting and scraping hard scaled and bony fish is very similar to polish developing from bone cutting or meat butchering (with bone present). This is consistent with observation made by Gijn (1989). Gijn on the basis of her study of her experiments with fish points out that the wear resulting from cleaning fish consists of three types of polish: A) a rough, corrugated band of greasy polish. This polish developed irrespective of the cleaning task performed, and is very characteristic of fish working. The polish was also quickly adsorbed by clay minerals. B) Randomly distributed linear streaks of matt polish, very characteristic, but only developing when hard scales are contacted. C) A smooth, bright polish, virtually indistinguishable from the type of polish resulting from bone contact. This polish develops only when fish bones are touched. It is a very durable polish, probably attributable to abrasion.

Both A and B type wear attributes are either very vulnerable or else not distinctive and type C is only produced when a bony fish is worked on. Thus tracing fish cleaning or scraping activities in an archaeological assemblage can be a very difficult enterprise.

It is thus not surprising that fish as a contact material appears in so few determination lists of wear analyses of archaeological assemblages. At the Dutch site of Hekelingen III -- the main reason for settlement was the possibility of constructing a trap, enabling the inhabitants to catch a great number of fish within a short time. The majority of fish was probably processed on the site. However even at this site tools with fish polish are virtually absent. Aside from the possibility that the author may have overlooked the traces, she postulates a behavioral explanation for the absence of such a polish in the deposits. Analysis of the remains has shown that sturgeon was the important species exploited here. Sturgeon is a very bony fish. Thus we can assume that most of the fish working tools functioned in cleaning of large number of sturgeons may have been interpreted as bone working tools. The other species of fish caught at or near the site were probably more isolated occurrences than the catch of the anadromous sturgeon. Implements used to clean these supplemental species of fish were more likely to exhibit polish type A or B, because of contact with scales. Although it may be difficult to trace fish cleaning activities in the archaeological record, it is certainly not impossible. Absence of these traces, however, does not necessarily mean that fish cleaning activities did not take place.

Experiment 14 and 15: Cutting Bone (Figure 8)

In these experiments two retouched blade tools were used for cutting bone for 30 minutes. The tools are then washed and observed under 200X. Both the dorsal and ventral faces of the tools have isolated spots of bright polish with a rough and greasy luster. One distinctive feature of bone working is the formation of innumerable pits on

the polish surface and a flat topography. There are very deep and narrow striations on the tool edge.

Experiment 16 – 18: Shooting Experiments (Figure 9)

In these sets of experiments 3 projectiles (2 triangles and one point) were used to shoot in the ground directly at a close range several times with the help of a bow and an arrow. The tools are then collected and cleaned. They are then observed under a microscope. There is damage from impact on all the tools. On all the tools the tip is broken and it can be seen even with naked eye. On two projectiles there is a linear streak of polish and striations are seen parallel to impact. One of the projectiles was also observed under SEM. The impact damage and fracture scars on the projectile are very prominent under the SEM.

Experiments 19 – 21: Scraping and Cutting Roots and Tubers (Figure 10)

In these experiments 2 unretouched blade tools and 2 scrapers were used to cut and scrape roots (Ginger) and tubers (Cyperus/ Motha). The tools were used for an half an hour to two hours. The experiments were conducted on both washed and unwashed (with dirt and grit) roots and tubers to see the effects. The tools were then cleaned and observed under the microscope. The results for the tools used for washed material and unwashed materials are very different. The tools used on washed material have only developed a very thin line of bright polish with no edge damage (just like polish from meat cutting without the greasy luster). The tool used on unwashed materials for two hours developed well developed bright and very matt and rough and flat polish with no

directionality. Striations are present and are very deep. There was extensive edge damage in form of scars. The results of the experiments are consistent with Sievert (1992) show that traces from processing roots and tubers produce some characteristic features (1) slow to form but they do become visible on extensive use on unwashed materials (2) directionality is absent and the polish is invasive and tapers off the edge (3) striations when present are long and very deep

Experiments 22 – 27: Reaping Cereals (Figure 11)

A total of 6 experiments are performed on wheat. The tools used for the experiments were sickles and retouched blades. The total harvesting time amounted to 5 hours and 10 minutes (Time spent with each tool varied from 30 minutes to 2 hours). Use retouch developed on four tools. On two tools the gloss could be seen with naked eyes. The results observed conformed to those reported by others (Anderson 1992; Gijn 1989 and Unger Hamilton 1992). In all the instances a wide band of highly reflective, very smooth polish with clear parallel directionality and a few striations occurred. The edge rounding was prominent but varied with the duration of work. The topography is domed. Striations are deep.

Experiments 28 – 34: Cutting Reeds and Grasses (Figure 12)

Four tools (unretouched blades) were used for cutting reeds. The experiments were performed on both fresh and dry reeds. The tools were used for half an hour to one hour. The use on dry reed produced edge damage in form of micro-scars/half moon shaped scars with feather termination and is irregularly spaced. The polish has a metallic

texture which has only been seen in on tools used for cutting dry reeds (Gijn 1980). Fresh reed cutting produced smooth and wet looking polish with slight edge rounding and a well defined reflective polish with domed topography.

Three tools were used to cut grass (munj grass). Grasses also produce a well defined band of polish along the edge of the tools. In general this band is much narrower around half a cm in this case, than the ones produced by the reeds or domesticated cereals. According to Gijn (1989) this is due to the thickness of the stem of the plants involved.

Experiment 35 and 36: Trampling

Two experiments were performed with the help of two retouched flakes to replicate the effect of trampling on the surface of the flint. Flakes were buried and trampled for a month. On observation the tool show randomly distributed edge damage. There was distinct a bright sheen possible from rubbing against the soil. One of the tools shows deep scratches.

Experiments 37: Scraping Pottery

In this experiment a tool is used for scraping pottery for thirty minutes. On observation under the microscope use retouch is absent. There is slight edge rounding. Polish is highly reflective and is in form of a large band perpendicular to the edge. It is reticulated and its texture is smooth and matt. The topography is domed.

Experiment 38: Rubbing Tools against each other

In this experiment tools were intentionally rubbed against each other. The tool was kept in a bag with other tools and some rocks and they were intentionally rubbed and shaken and dropped. The tool was then cleaned and observed under microscope. There is extensive damage and rounding on the edge of the tool. The tool also showed gloss from friction.

Experiment 39: Rubbing Tool against the Microscope (Figure 13)

In this experiment an unretouched flake was rubbed again the microscope for 30 minutes. The tool did not show any edge rounding or scars but it had very well developed linear streaks of metallic looking polish.

Experiments 40 – 44: Wood Working Experiments (Figure 14 – 15)

In these experiments 4 microlithic tools (1 blade, 2 unretouched blades and 1 scraper) were used for cutting and scraping hard wood (Neem) and soft wood (Banana tree) for thirty minutes each. Another scraper was used to whittle the bark off a branch of a Neem tree for thirty minutes. The tools were then cleaned and studied under 200 X and 400 X.

Polish texture is rough and matt on the tools used for cutting and scraping. Wear is extremely pronounced in the tool used for cutting hard wood. Type of wood effects the edge removal. Harder wood causes more edge damage than softer species. Fresh wood inflicted less damage than dry wood. This is because dry wood is more resistant. Edge removal was absent in the tool used for scraping/transverse motion. Retouch is

deep and well defined scalar, half moon or trapezoidal in shape. Polish distribution varied from reticulated, isolated spots to a band along the edge. Striations were formed on only one of the tools. The striations are narrow and deep. In all the tools the extent of retouch exceeds polish.

The microwear from scraping experiment shows linear distributed matt streaks of polish on the ventral surface of the tool. On the dorsal surface numerous small fractures are seen. The polish is very bright and smooth. The topography is domed. It is important to note that whittling of wood bark creates more striations than any other activities conducted. According to Keeley (1980: 36) this is due to the fact that there is a greater abundance of grit and dirt and other environmental dust in the bark than the wood.

Keeley considered (1985: 36) wood polish to be very distinct. Moss also had similar observation although she did note that it was sometimes similar to antler polish. However in blind tests conducted by microwear analysts the identification of wood polish has been one of the most difficult (Unrath et al. 1986). This may be due to the fact that wood polish is slow to form and goes through stages of development which vary in appearance (Gijn 1989; Vaughan 1985: 33).

Experiment 45 – 47: SEM Experiments to Characterize the Developmental Process of Dry Hide Polish (Figures 16 – 17)

The purpose of these experiments was to study the effect of dry hide on a blade tool used for scraping. The tools were used for 10 and 30 minutes and 1 hour and then studied under SEM. Use on hide produces a very characteristic change in the microtopography of the tool 1. Under 1500 X magnification the tool shows a knobbly

surface on the outermost edge. In the direction of the work shallow linear features are visible. This area consists of small caps with well defined circumference. These features become more prominent on the tools used for 30 minutes and very well developed on the tool used for an hour.

Experiment 48 – 50: SEM Experiments on Tools used for Boring Wood (Figure 18)

Three points were used for drilling wood. They are then examined under SEM at the 1500 magnification. Drilling wood makes very distinct changes in the microtopography. Surface cracks and linear feature striations were observed on the tip of the point. The striations are surrounded by few impact pits

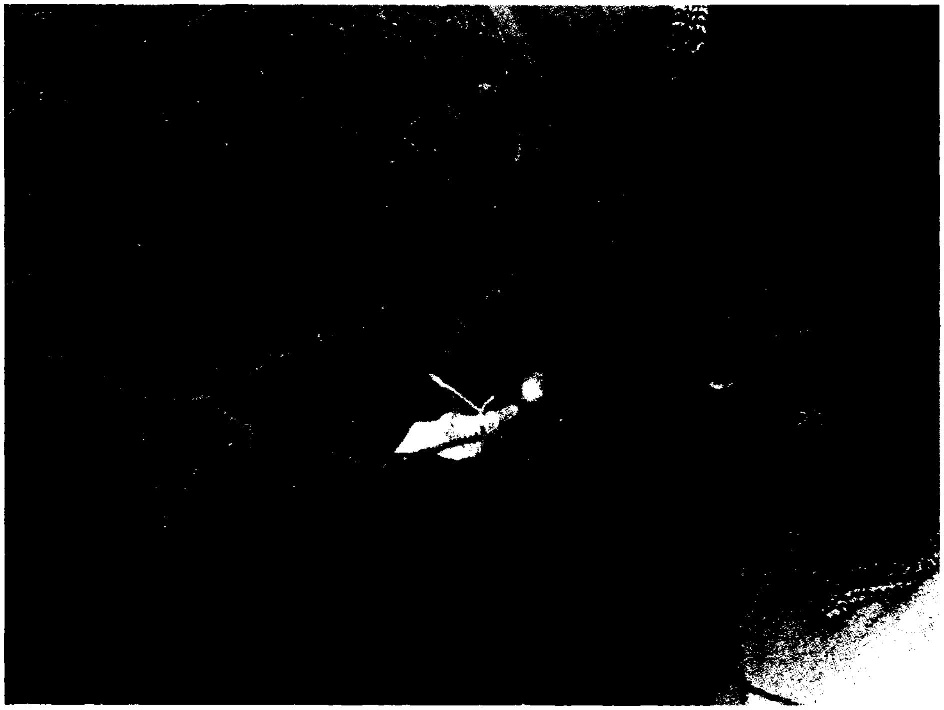

Figure 1: Cutting Dry Reed with a Sickle

Figure 2: Harvesting Mustard with a Blade

Figure 3: Scraping Root (*Cyperus rotundus*) with an End Scraper

Figure 4: Whittling Wood with a Scraper

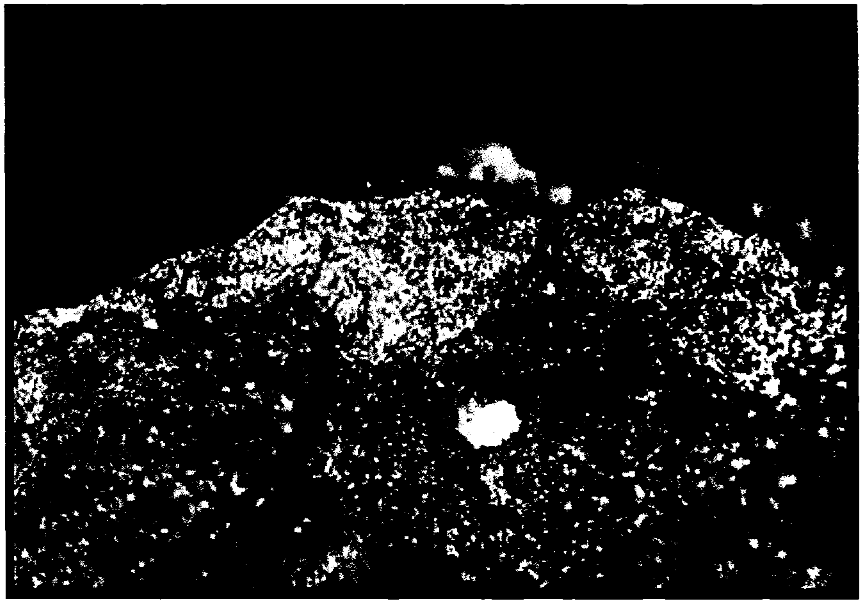

Figure 5: Polish from Dry Hide Work (300 X)

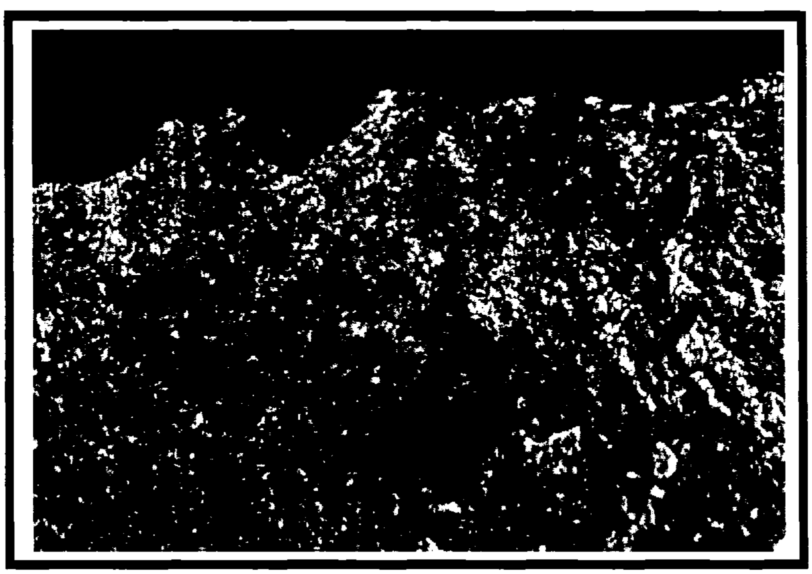

Figure 6: Polish from Butchering Meat/Fish (300X)

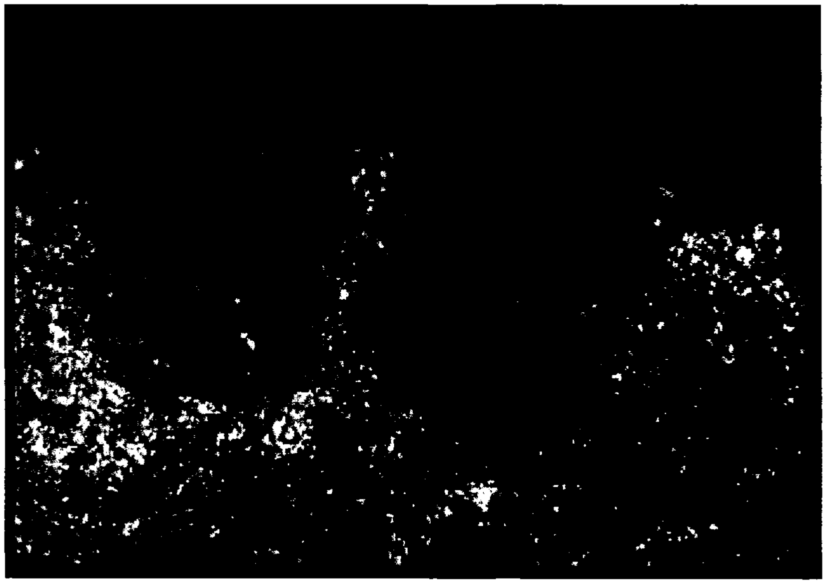

Figure 7: Polish from Scraping Hard Scale Fish (300 X)

Figure 8: Polish from Cutting Bone (400 X)

Figure 9: SEM Picture of Impact Damage (1500 X)

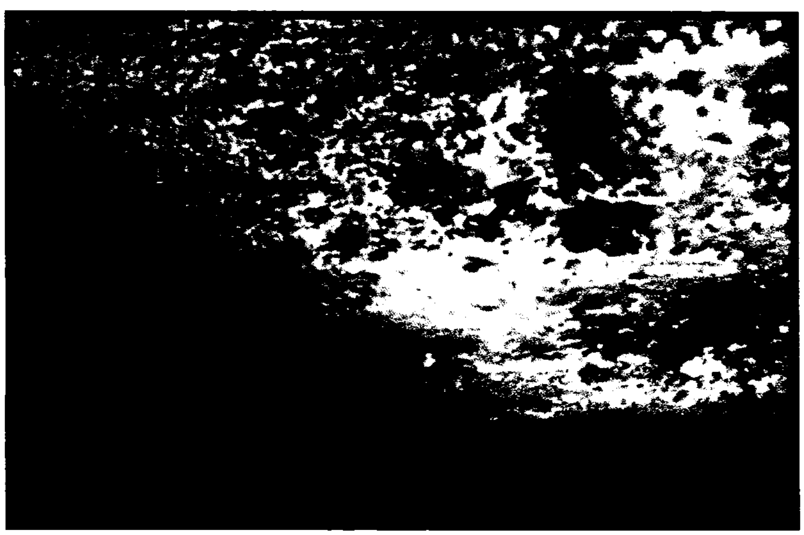

Figure 10: Polish from Scraping Roots (400 X)

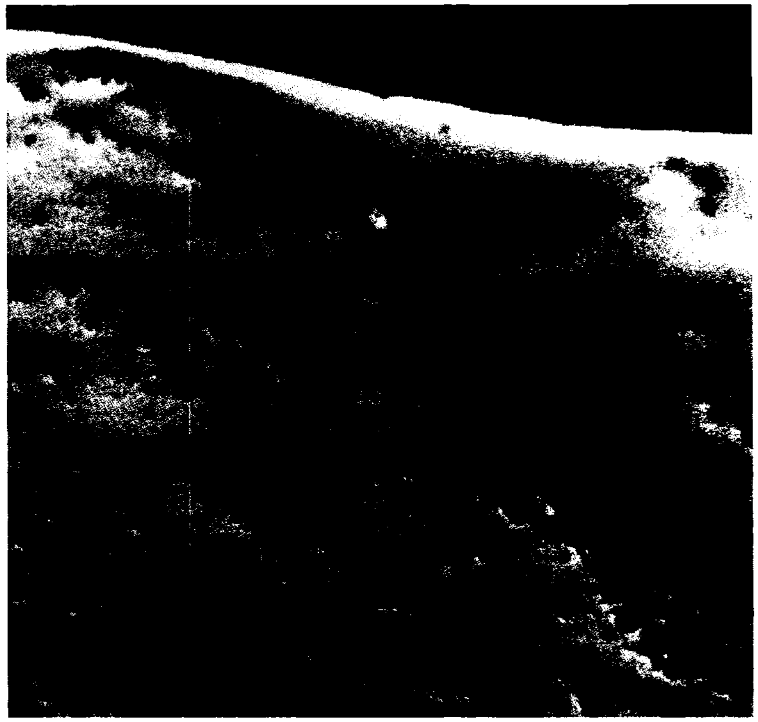

Figure 11: Cereal Polish (400 X)

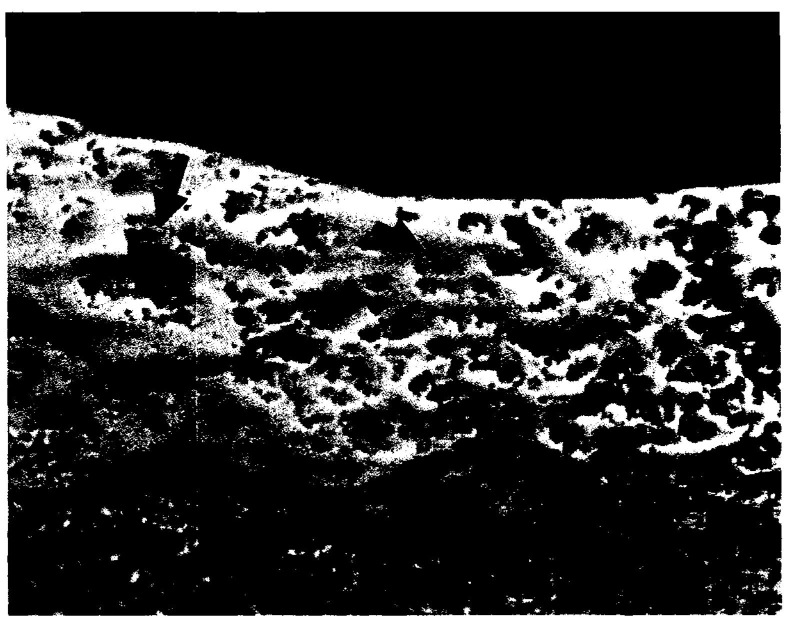

Figure 12: Polish from Cutting Reed (400 X)

Figure 13: Use wear from rubbing Tool against the Microscope (400 X)

Figure 14 Characteristic Features from Wood Working or Soft Wood (300 X)

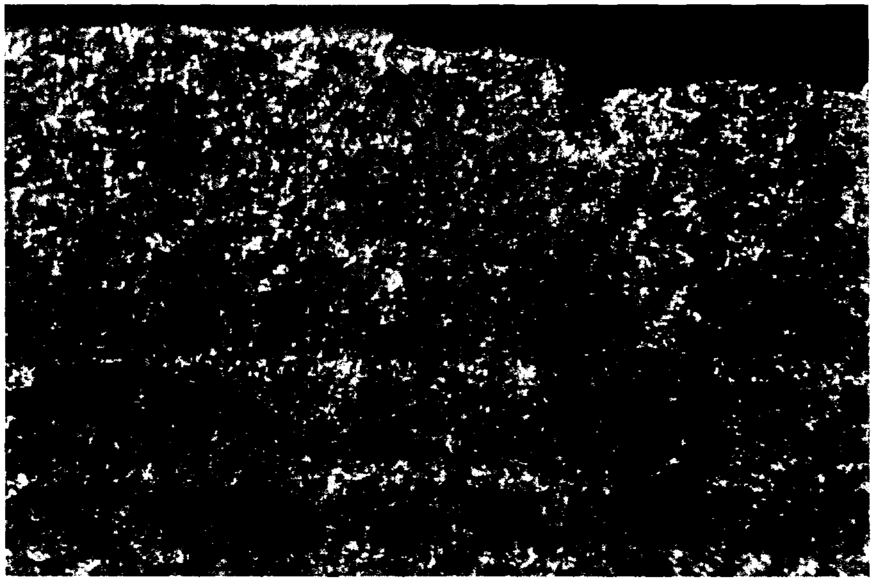

Figure 15: Characteristic Traces from Whittling Wood (300 X)

Figure 16: SEM Picture of Characteristic Traces from 15 minutes of Dry Hide Work (1500 X)

Figure 17: SEM Picture of Progression of Characteristic Traces from 1 hour of Dry Hide Work (1500 X)

Figure 18: SEM Picture of Characteristic Traces from Drilling Wood (1500 X)

APPENDIX C

ACERAMIC TOOL AND ASSOCIATED ACTIVITIES

This appendix provides an in depth information about the Aceramic tool types studied for use wear analysis. Tool type, its metrical attributes, excavation information and activity performed with is laid out here. The Appendix also provides the microphotographs of the associated activities (Figures 19 - 29).

Tool Type	Length	Breadth	Thick	Trench/ Lot	Depth	Use	Activity
1. Blade	26.14	10.23	4.19	1A/1007	- 50 cm	Yes	Transverse action soft animal
2. Blade	19.84	5.87	1.26	1A/1007	- 50 cm	Yes	Scrape wet hide
3. Blade	15.48	4.14	1.35	1A/1007	- 50 cm	Yes	Longitudinal action soft plant
4. Blade	25.56	8.79	3.49	1A/1007	- 50 cm	Yes	Whittle Wood
5. Blade	17.25	8.32	1.98	1A/1007	- 50 cm	Yes	Cut siliceous plant
6. Blade	20.64	5.75	1.99	1A/1007	- 50 cm	No	Absent
7. Blade	13.9	8.13	2.21	1A/1007	- 50 cm	Yes	Cut siliceous plants
8. Blade	10.72	6.62	1.9	1A/1007	- 50 cm	No	Absent
9. Blade	12.86	5.69	2.06	1A/1008	- 63 cm	No	Absent
10. Blade	12.69	4.63	1.33	1A/1008	- 63 cm	No	Absent
11. Blade	18.39	4.49	1.45	1A/1008	- 63 cm	No	Absent
12. Blade	14.11	5.13	1.31	1A/1008	- 63 cm	Yes	Whittle wood

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot no.	Depth	Use	Activity
13. Blade	10.69	6.07	1.22	1A/1008	- 63 cm	Yes	Cut siliceous plants
14. Blade	16.28	4.35	1.33	1A/1008	- 63 cm	Yes	Meat/Fish butchering
15. Blade	14.44	5.17	1.46	1A/1009	- 72 cm	Unsure	Undetermined
16. Blade	15.62	4.94	2.2	1A/1009	- 72 cm	Yes	Meat/Fish Butchering **(Figure 19)**
17. Blade	13.6	9.93	1.77	1A/1010	- 82 cm	Yes	Meat/Fish butchering
18. Blade	9.13	6.34	1.54	1A/1010	- 82 cm	No	Absent
19. Blade	20.36	4.14	2.17	1A/1010	- 82 cm	Yes	Scrape roots and tubers **(Figure 20)**
20. Blade	13.34	3.59	1.64	1A/1010	- 82 cm	Yes	Transverse action soft animal
21. Blade	28.78	5.76	3.14	1A/1010	- 82 cm	Unsure	Undetermined
22. Blade	21.28	6.38	2.47	1A/1011	- 82 cm	Yes	Whittle Wood **(Figure 21)**
23. Blade	23.7	7.1	3	1A/1012	- 106 cm	Yes	Meat/Fish butchering
24. Blade	14.8	6.83	1.89	1A/1012	- 106 cm	Yes	Transverse soft animal
25. Blade	9.59	3.61	0.37	1C/3008	- 54 cm	Yes	Scrape roots and tubers
26. Blade	15.54	7.44	1.55	1C/3008	- 54 cm	Yes	Scrape roots and tubers
27. Blade	16.54	7.24	1.64	1C/3008	- 54 cm	Unsure	Undetermined
28. Blade	26.25	15.96	3.47	1C/3009	- 60 cm	Yes	Scrape wet hide
29. Blade	15.37	6.04	1.76	1C/3016	No depth	Yes	Whittle soft wood

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot no.	Depth	Use	Activity
30. Blade	10.73	4.7	1.68	1C/3018	-64 cm	Yes	Cut roots and tubers
31. Blade	10.73	4.7	1.68	1C/3018	-64 cm	Yes	Absent
32. Blade	15.07	9.87	2.69	1C/3018	-64 cm	Yes	Multipurpose
33. Blade	15.75	5.88	1.78	1C/3018	-64 cm	Yes	Multipurpose
34. Blade	18.7	9.08	4.83	1C/3019	No depth	No	Absent
35. Blade	12.09	6.89	1.06	1C/3019	No depth	No	Absent
36. Blade	11.03	4.37	1.37	1C/3021	No depth	No	Absent
37. Blade	10.06	3.49	1.56	1C/3021	No depth	Unsure	Undetermined
38. Blade	14.89	6.78	1.57	1C/3021	No depth	Not Interpreted	PDSM
39. Blade	21.55	5.97	2.54	1C/3021	No depth	Yes	Scrape wet hide
40. Blade	12.12	6.07	1.25	1D/4008	No depth	No	Absent
41. Blade	15	5.07	1.51	1D/4008	No depth	No	Absent
42. Blade	9.1	6.51	1.89	1D/4008	No depth	No	Absent
43. Blade	15.83	5.85	2.02	1D/4008	No depth	Unsure	Undetermined
44. Blade	17.92	4.34	2.18	1D/4008	No depth	Yes	Scrape wet hide
45. Blade	11.41	4.79	1.29	1D/4008	No depth	Yes	Cut roots and tubers
46. Blade	19.67	8.51	2.03	1E/5007	No depth	Yes	Meat/Fish butchering

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thick	Trench Lot No.	Depth	Use	Activity
47. Blade	17.44	9.57	1.25	1E/5008	No depth	Yes	Transverse soft animal
48. Blade	22.19	4.14	2.53	1E/5008	No depth	Yes	Whittle wood
49. Blade	12.2	6.59	1.93	1E/5009	No depth	No	Absent
50. Blade	18.74	8.45	2.81	1E/5009	No depth	Not Interpreted	PDSM
51. Blade	22.78	7.32	2.04	1F/6004	No depth	Same	PDSM
52. Blade	12.2	4.3	1.02	1A/1009	-72 cm	No	Absent
53. Blade	13.61	4.34	2.54	1A/1009	-72 cm	Yes	Transverse soft animal
54. U. Blade	11.42	6.91	2.64	1A/1010	-82 cm	No	Absent
55. U. Blade	16.34	5.88	1.29	1A/1012	-106 cm	Yes	Multipurpose
56. U. Blade	14.65	4.63	1.05	1A/1012	-106 cm	No	Absent
57. U. Blade	13.64	5.77	2.17	1A/1012	-106 cm	Yes	Multipurpose
58. U. Blade	15.85	6.64	1.78	1E/5007	-106 cm	No	Absent
59. U. Blade	18.72	8.65	2.7	1E/5007	-106 cm	No	Absent
60. U. Blade	14.87	4.21	1.3	1E/5007	-106 cm	Yes	Multipurpose
61. U. Blade	11.27	5.3	1.5	1E/5007	-106 cm	Unsure	Undetermined
62. U. Blade	12.47	6.45	1.97	1E/5007	-106 cm	Yes	Multipurpose
63. U. Blade	12.02	4.15	1.47	1E/5007	-106 cm	Yes	Medium plant material

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thick	Trench	Depth	Use	Activity
64. U. Blade	22.19	4.14	2.53	1E/5008	No depth	No	Absent
65. U. Blade	17.44	9.57	1.25	1E/5008	No depth	No	Absent
66. U. Blade	12.94	5.37	1.32	1E/5009	No depth	Yes	Meat/Fish Butchering
67. U. Blade	25.65	7.54	1.91	1E/5009	No depth	Yes	Cut roots and tubers
68. U. Blade	16.05	7.03	1.93	1E/5009	No depth	Yes	Multipurpose
69. U. Blade	17.03	10.09	1.27	1E/5009	No depth	Yes	Transverse Action medium plant
70. U. Blade	14.9	9.19	3.41	1A/1007	-50 cm	No	Absent
71. U. Blade	13	6.52	1.8	1A/1007	-50 cm	Yes	Scraping hide
72. U. Blade	16.63	7.4	2.17	1A/1010	-82 cm	Yes	Cut roots and tubers
73. U. Blade	15.24	11.23	2.71	1A	-82 cm	No	Absent
74. U. Flake	10.72	6.62	1.9	1A/1007	-50 cm	Yes	Pierce Hard Plant
75. U. Flake	13.4	8.13	2.21	1A/1007	-50 cm	Yes	Cut Grass
76. U. Flake	12.01	7.34	3.69	1B/2021	No depth	Yes	Awl to puncture Hide/Skin
77. U. Flake	17.22	10.47	2.02	1B/2024	-66 cm	Not Interpreted	PDSM
78. U. Flake	10.48	10.41	1.68	1C/3008	No depth	same	PDSM
79. U. Flake	8.76	5.74	1.32	1C/3019	No depth	Yes	Longitudinal Soft Plant **(Figure 22)**
80. U. Flake	14.38	7.34	2.43	1E/5007	No depth	No	Absent
81. U. Flake	13.4	5.84	1.88	1E/5007	-106 cm	Unsure	Undetermined

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thickness	Trench/ Lot No.	Depth	Use	Activity
82. U. Flake	12.57	6.43	1.43	1E/5007	-106 cm	Yes	Meat/Fish Butcher
83. U. Flake	14.67	8.13	1.9	1E/5007	-106 cm	No	Absent
84. Triangle	22.06	6.69	2.07	1A/1008	-63 cm	Yes	Shoot Animal
85. Triangle	17.58	4.77	1.73	1A/1008	-63 cm	Not interpreted	PDSM
86. Triangle	11.4	3.43	1.13	1A/1009	-72 cm	No	Absent
87. Triangle	17.68	4.92	1.97	1A/1012	-106 cm	No	Absent
88. Triangle	18.48	7.28	1.94	1B/2024	-66 cm	Yes	Shoot Animal
89. Triangle	14.22	4.57	2.35	1B/2024	-66 cm	No	Absent
90. Triangle	23.11	11.67	2.57	1C/3009	-66 cm	Yes	Shoot Animal
91. Triangle	14.08	3.83	2.35	1C/3008	-54 cm	Yes	Shooting Animal
92. Triangle	12.68	6	2.06	1C/3008	-54 cm	No	Absent
93. Triangle	10.67	6.94	0.34	1C/3008	-54 cm	Yes	Shoot Animal
94. Triangle	10.41	5.05	1.4	1C/3008	-54 cm	Yes	Shoot Animal
95. Triangle	10.88	5	1.16	1C/3008	-54 cm	No	Absent

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thickness	Trench/ Lot No.	Depth	Use	Activity
96. Triangle	16.32	5.5	2.7	1C/3008	-54 cm	Yes	Shoot Animal
97. Triangle	14.87	7.75	1.61	1C/3008	-54 cm	No	Absent
98. Triangle	11.35	4.94	0.81	1C/3008	-54 cm	No	Absent
99. Triangle	14.31	5.77	2.83	1C/3008	-54 cm	Yes	Shoot Animal
100. Triangle	14.06	3.64	2.55	1C/3008	-54 cm	No	Absent
101. Point	14.48	4.49	1.37	1A/1007	-50 cm	Yes	Awl to puncture hide
102. Point	16.9	9.28	1.46	1A/1007	-50 cm	Yes	Absent
103. Point	21.04	5.57	1.23	1A/1007	-50 cm	Yes	Awl to puncture hide
104. Point	15.49	3.69	1.07	1A/1007	-50 cm	No	Absent
105. Point	12.21	3.06	1	1A/1008	-63 cm	Not interpreted	PDSM
106. Point	14.36	4.35	1.76	1A/1008	-63 cm	Yes	Pierce hard plant material
107. Point	13.06	4.91	2.43	1A/1008	-63 cm	Yes	Drill wood
108. Point	15.26	4.11	1.22	1A/1008	-63 cm	No	Absent
109. Point	15.31	3.15	1.38	1A/1008	-63 cm	Yes	Drill hide to ream holes
110. Point	12.74	5.43	2.17	1A/1008	-63 cm	No	Absent

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thickness	Trench/ Lot No.	Depth	Use	Activity
111. Point	16.41	4.43	2.72	1A/1008	-63 cm	No	Absent
112. Point	15.31	6.07	1.13	1A/1008	- 63 cm	No	Absent
113. Point	16.88	4.86	1.42	1A/1008	- 63 cm	No	Absent
114. Point	13.94	3.17	1.34	1A/1009	- 72 cm	Yes	Pierce Hard Plant
115. Point	13.55	4.5	1.85	1A/1009	- 72 cm	Yes	Drill Hide
116. Point	13.4	4	1.6	1A/1009	- 72 cm	Yes	Awl to Puncture Hide
117. Point	15.23	6.17	3.71	1A/1010	- 82 cm	No	Absent
118. Point	14.72	5.58	2.87	1A/1010	- 82 cm	No	Absent
119. Point	12.36	3.09	0.99	1A/1010	- 82 cm	No	Absent
120. Point	8.03	3.54	1.64	1A/1010	- 82 cm	Yes	Pierce hard plant
121. Point	19.9	4.27	1.66	1A1012	- 106 cm	Yes	Drill hide to ream holes
122. Point	16.17	5.78	1.72	1B/2011	- 53 cm	Yes	Pierce Hard Wood **(Figure 23)**
123. Point	37.61	5.56	4.36	1B/2020	No depth	Yes	Drilling Hide to ream holes
124. Point	13.81	4.8	1.8	1B/2024	- 66 cm	No	Absent
125. Point	13.04	2.14	1.56	1C/3008	- 54 cm	No	Absent
126. Point	20.39	4.93	3.17	1C/3008	- 54 cm	No	Absent
127. Point	26.85	5.72	2.72	1C/3009	No depth	Yes	Awl to Puncture Hide
128. Point	15.47	3.7	1.43	1C/3016	No depth	No	Absent

APPENDIX C (CONTD.)

Tool Type	Length	Breadth	Thickness	Trench/ Lot No.	Depth	Use	Activity
129. Point	13.71	2.54	1.03	1C/3021	No depth	Yes	Shoot Animal **(Figure 24)**
130. Point	12.43	3.67	1.96	1C/3021	No depth	Yes	Shoot Animal **(Figure 25)**
131. Point	9.54	4.1	1.99	1C/3021	No depth	Yes	Shoot Animal
132. Point	18.56	6.16	2.27	1D/4008	No depth	Not - interpreted	PDSM
133. Point	10.56	3.04	1.52	1D/4008	No depth	No	Absent
129. Point	13.71	2.54	1.03	1C/3021	No depth	Yes	Shoot Animal **(Figure 24)**
134. Point	13.05	4.65	1.39	1E/5007	No depth	Yes	Shoot Animal
135. Point	24.78	5.22	1.63	1E/5007	No depth	Unsure	Undetermined
136. Point	17.81	4.24	1.28	1E/5009	No depth	Yes	Drill Hide to ream hole
137. Point	23.62	5.78	2.62	1F/6004	No depth	No	Absent
138. Scraper	12.01	7.34	3.69	1B/2021	No depth	Yes	Cut roots and tubers
139. Scraper	40.82	20.47	7.8	1B/2026	No depth	Yes	Meat/Fish Butchering
140. Scraper	18.94	15.34	4.07	1B/2026	No depth	No	Absent
141. Scraper	17.61	16.12	5.1	1B/2030	No depth	Unsure	Undetermined
142. Scraper	15.67	12.76	2.13	1C/3009	No depth	Yes	Scrape Hide **(Figure 26)**

APPENDIX C (CONTD.)

143. Scraper	10.51	5.64	1.49	1E/5007	No depth	Yes	Scrape Hide
144. Scraper	11.75	6.4	0.92	1E/5009	No depth	No	Absent
145. Scraper	9.09	5.41	1.2	1E/5009	No depth	Yes	Scrape Hide
146. Scraper	9.66	6.09	0.71	1E/5009	No depth	Yes	Multipurpose
147. Scraper	15.93	7.47	1.47	1E/5009	No depth	Yes	Multipurpose
148. Scraper	11.44	4.56	0.96	1E/5009	No depth	Not Interpreted	PDSM
149. Scraper	10.65	6.96	1.55	1E/5009	No depth	Yes	Meat/Fish Butchering
150. Scraper	15.48	11.26	1.75	1E/5009	No depth	No	Scrape Soft Animal Material (Hide) **(Figure 27)**

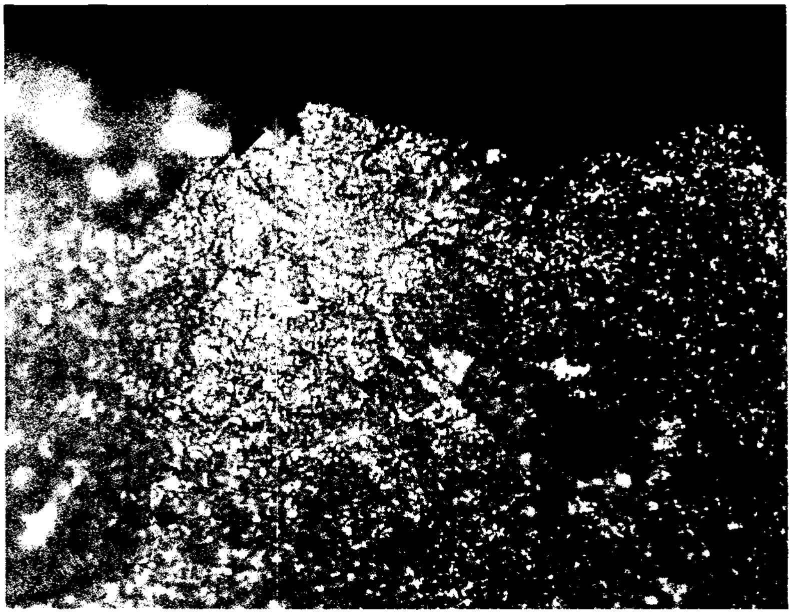

Figure 19: Characteristic Polish from Butchering Meat (artifact no. 16, 400X)

Figure 20: Polish from Scraping Roots and Tubers (artifact no. 19, 300X)

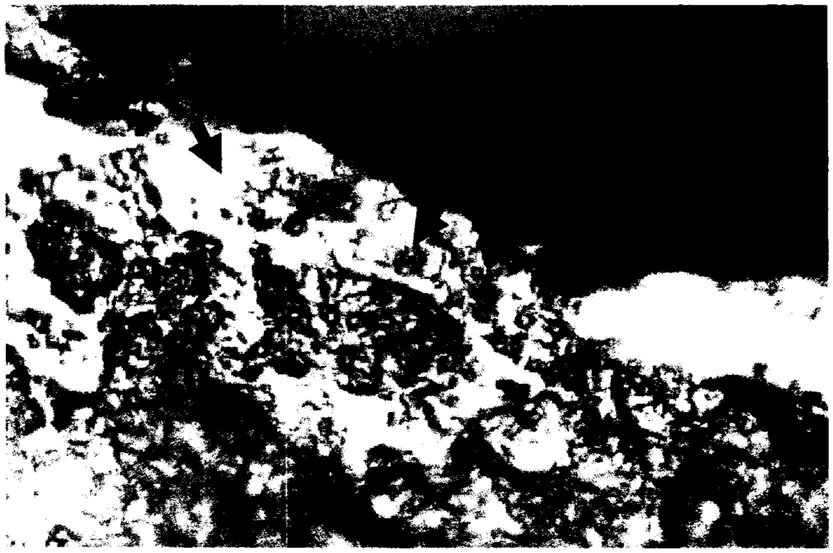

Figure 21: Characteristic Polish from Whittling Wood (artifact no. 22, 400X)

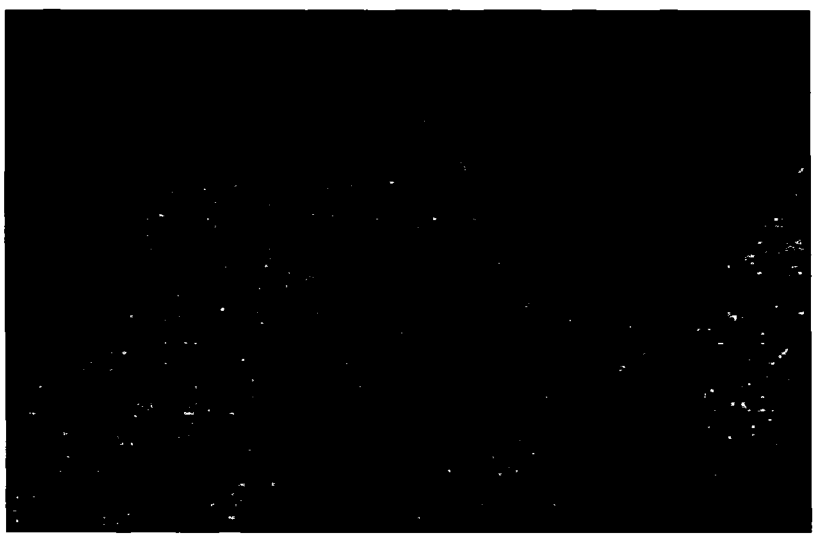

Figure 22: Polish from Cutting Soft Plant (artifact no. 79, 300X)

Figure 23: SEM picture of characteristic features from Drilling Wood (artifact no. 122, 1500X)

Figure 24: Linear Streaks on a Point from being used as a Projectile (artifact no. 129, 400X)

Figure 25: SEM picture of evidence of Fracture on a Point from being used as a Projectile (artifact no. 130)

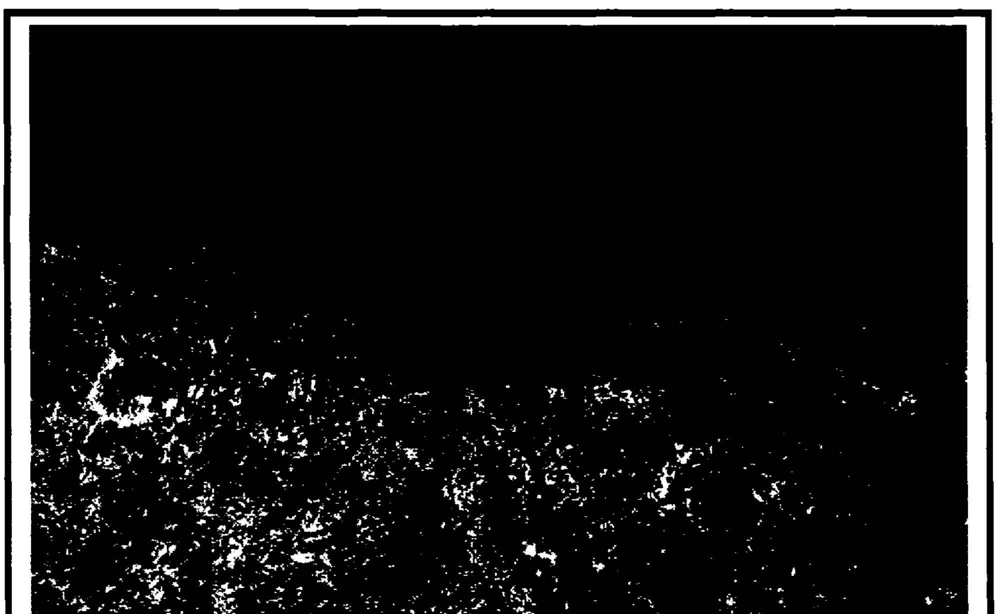

Figure 26: Characteristic Polish from Scraping Dry Hide (artifact no. 142, 300 X)
Slightly rounded edges – expedient use

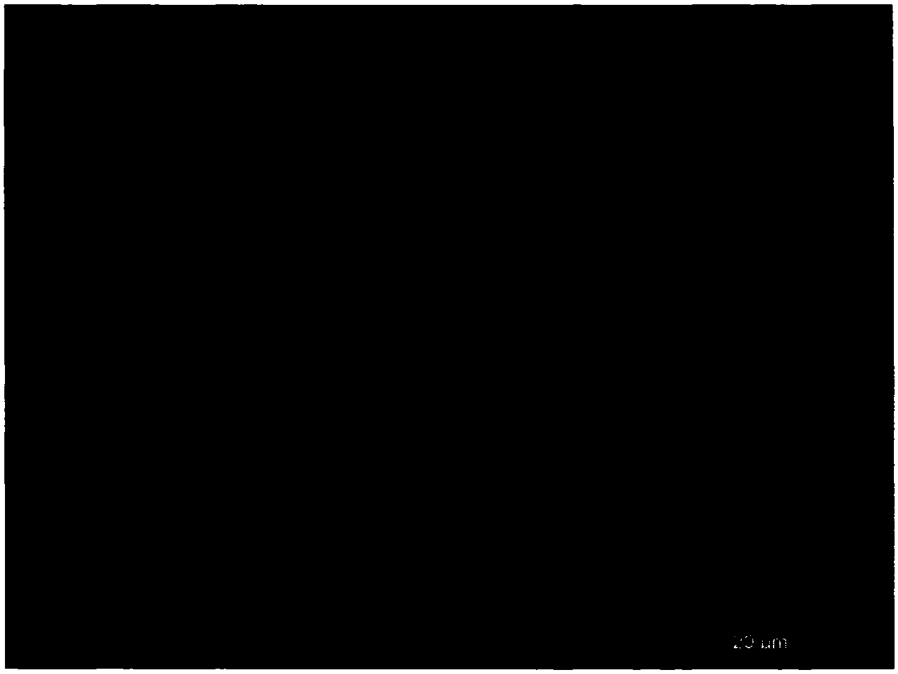

Figure 27: SEM picture of characteristic features from Scraping Dry Hide (artifact no. 150, 1500X)

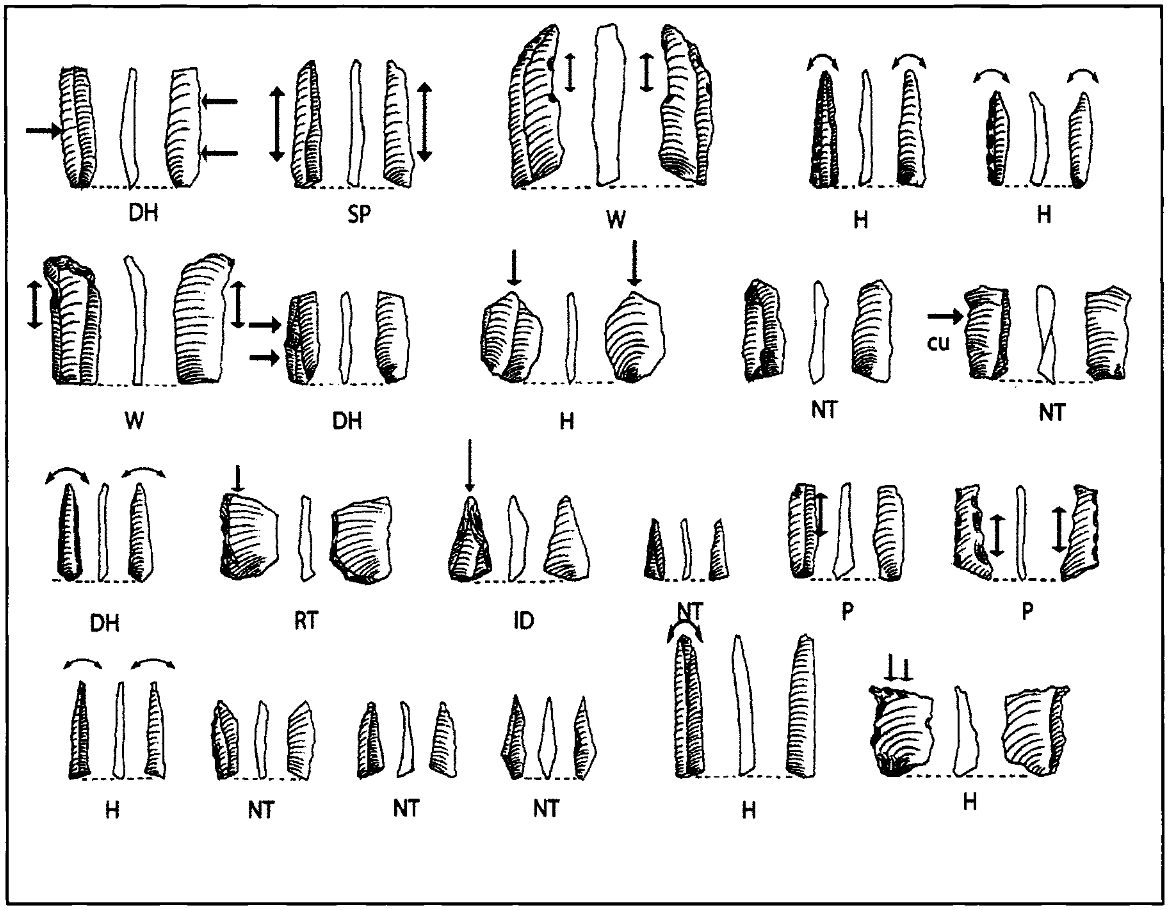

Figure 28: Aceramic Phase Artifacts Studied for Use-Wear Analysis

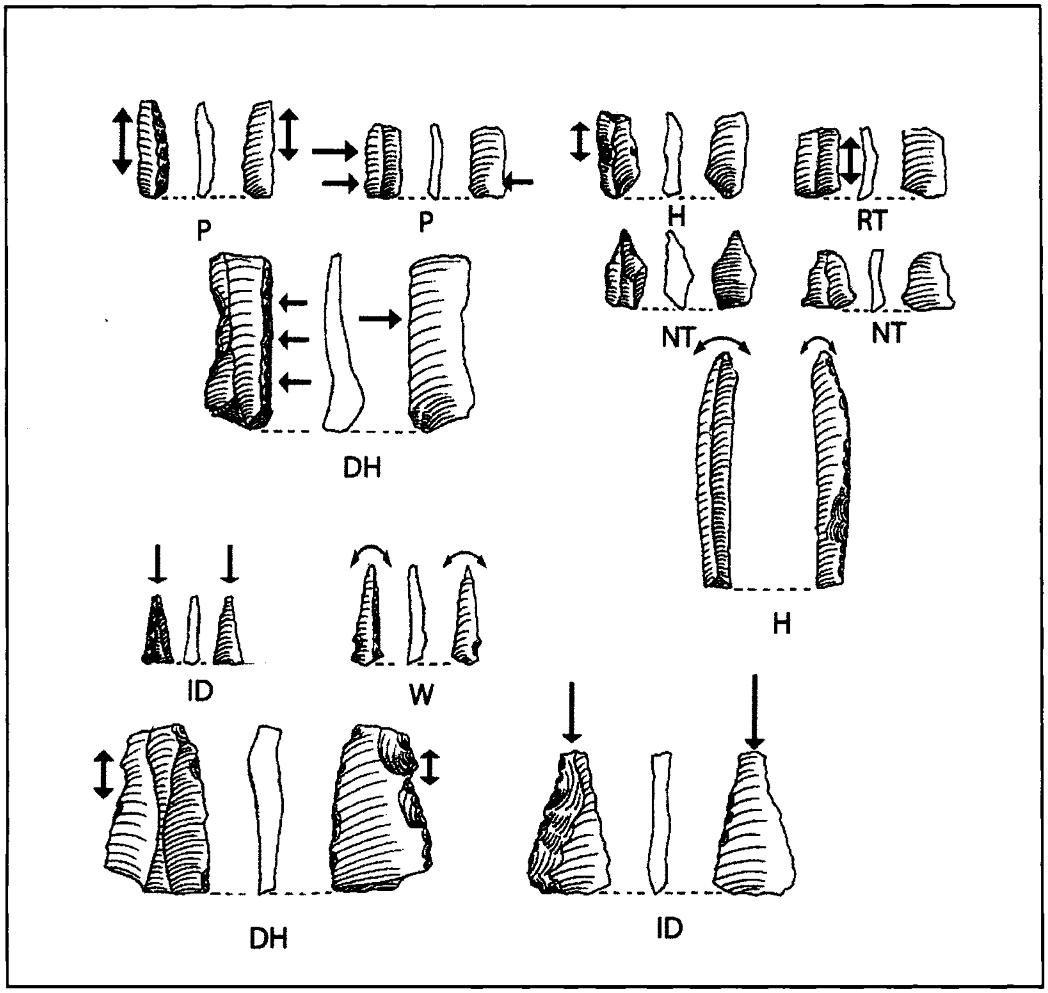

Figure 29: Aceramic Phase Artifacts Studied for Use-Wear

APPENDIX D

CERAMIC TOOL TYPES AND ASSOCIATED ACTIVITIES

This appendix provides an in depth information about the Ceramic tool types studied for use wear analysis. Tool type, its metrical attributes, excavation information and activity performed are presented here. The Appendix also provides the microphotographs of the associated activities (Figures 30 - 33).

Tool Type	Length	Breadth	Thick	Trench	Depth	Use	Activity
1. Crescent	35.93	12.89	7.38	1A/1001	-8 cm	Yes	Harvesting Cereal
2. Crescent	13.57	3.5	0.5	1B/2002	-23 cm	Not Interpreted	PDSM
3. Crescent	19.45	6.07	2.02	1B/2004	No depth	No	Absent
4. Crescent	14.07	3.78	2.13	1B/2010	No depth	No	Absent
5. Crescent	15.02	3.14	1.15	1B/2010	No depth	No	Absent
6. Crescent	18.58	5.14	2.98	1B/2010	No depth	Yes	Harvesting Cereal **(Figure 30)**
7. Crescent	12.38	3.22	1.66	1C/3006	-44 cm	No	Absent
8. Crescent	14.01	1.04	1.42	1C/3006	-8 cm	Yes	Harvesting Cereal
9. Crescent	12.92	3.71	1.39	1A/1005	-35cm	Not Interpreted	PDSM
10. Crescent	15.1	5.98	2.58	1A/1005	-35cm	No	Absent
11. Crescent	21.2	7.03	3.25	1A/1005	-35cm	Yes	Harvesting Cereal
12. Crescent	15.51	5.82	1.91	1A/1005	-35cm	Yes	Harvesting Cereal
13. Crescent	16.56	5.26	1.67	1A/1005	-35cm	Not Interpreted	PDSM

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
14. Crescent	9.68	5.45	1.49	1B/2005	-35cm	No	Absent
15. Crescent	8.58	4.2	1.71	1B/2005	-35cm	Yes	Harvesting Cereal
16. Crescent	12.86	5.05	2.13	1B/2005	-35cm	Yes	Harvesting Cereal
17. Crescent	13.72	6.03	1.98	1B/2005	-35cm	Yes	Harvesting Cereal
18. Crescent	13.09	4.97	1.62	1B/2005	-35cm	No	Absent
19. Crescent	14.1	5.73	2.09	1A	-24cm	Yes	Harvesting Cereal
20. Crescent	10.63	4.08	2.34	1A	-24cm	No	Absent
21. Crescent	12.81	5.49	2.12	1A	-24cm	Yes	Harvesting Cereal
22. Crescent	10.56	5.77	1.3	1A	-24cm	Yes	Harvesting Cereal
23. Crescent	21.05	8.54	1.84	1A	-24cm	No	Absent
24. Crescent	11.68	4.75	1.69	1A	-24cm	No	Absent
25. Crescent	12.29	3.84	1.52	1A	-24cm	No	Absent
26. Crescent	10.6	3.54	1.08	1A	-24cm	Yes	Cutting Soft grass
27. Crescent	24.41	6.12	2.54	1A	-24cm	Yes	Same
28. Crescent	14.1	5.73	2.09	1A	-24cm	Yes	Same
29. Crescent	10.63	5.03	2.34	1A	-24cm	No	Absent
30. Blade	35.63	17.94	3.14	1A/1003	-24cm	Yes	Soil

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
31. Blade	12.18	5.19	1.61	1A/1006	- 35 cm	Yes	Soil
32. Blade	13.13	3.58	1.49	1A/1006	- 35cm	Yes	Cut dry hide
33. Blade	17.28	5.11	2.02	1A/1006	- 35cm	Yes	Scrape wet hide
34. Blade	11.57	6.14	2.36	1A/1006	- 35cm	Not Interpreted	PDSM
35. Blade	13.85	4.22	1.51	1A/1006	-35cm	Unsure	Undetermine d
36. Blade	15.4	5.24	1.46	1A/1006	-35cm	Yes	Scraping Roots and Tubers
37. Blade	9.89	4.53	1.47	1B/2001	-13 cm	No	Absent
38. Blade	15.02	3.69	1.15	1B/2001	-13cm	Yes	Harvesting Cereal
39. Blade	12.75	4.14	1.28	1B/2002	- 23 cm	No	Absent
40. Blade	19.01	11.05	1.45	1B/2003	-23 cm	No	Absent
41. Blade	14.39	5.4	1.47	1B/2003	- 30 cm	Yes	Scraping Roots and Tubers
42. Blade	13.16	6.76	1.75	1B/2004	-30 cm	No	Absent
43. Blade	24.27	8.19	2.11	1B/2004	-30 cm	Unsure	Undetermine d
44. Blade	21.4	8.45	4.35	1B/2004	-30cm	Yes	Whittle Wood
45. Blade	23.68	2.73	1.87	1B/2005	- 35cm	Yes	Cereal Harvesting
46. Blade	15.60	8.17	2.86	1C/3007	- 49 cm	Yes	Multipurpose
47. Blade	12.96	4.18	1.38	1B/2005	-35 cm	Yes	Meat/ Fish Butchering **(Figure 31)**

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
48. Blade	13.12	4.54	1.63	1C/3005	-43 cm	Yes	Fish Scale Scraping
49. Blade	18.52	5.92	1.87	1C/3005	-43cm	Unsure	Undetermined
50. Blade	11.41	4.74	1.44	1C/3005	-43cm	No	Absent
51. Blade	12.32	4.03	1.36	1C/3007	-49 cm	Yes	Whittle Wood
52. Blade	11.01	4.51	2.21	1C/3007	-49cm	Yes	Cutting reed **(Figure 32)**
53. Blade	15.34	7.44	1.55	1C/3007	-49cm	No	Absent
54. Blade	16.54	7.24	1.64	1C/3007	-49cm	No	Absent
55. Blade	14.06	3.64	2.55	1C/3007	-49cm	Yes	Whittle Wood
56. Blade	11.35	4.94	0.81	1C/3007	-49cm	Yes	Cutting reed
57 Blade	14.67	7.75	1.61	1C/3007	-49cm	Not Interpreted	PDSM
58. Blade	16.32	5.5	2.7	1C/3007	-49cm	Yes	Cereal Harvesting
59. Blade	14.31	5.77	2.83	1C/3007	-49cm	No	Absent
60. Blade	13.38	6.25	2.34	1D/4001	-35 cm	No	Absent
61. Blade	20	6.67	4.72	1D/4001	-35cm	Yes	Cereal Harvesting
62. Blade	14.46	4.15	1.24	1D/4001	-35cm	No	Absent
63. Blade	14.96	4.5	1.64	1D/4001	-35cm	Yes	Cereal Harvesting
64. Blade	11.17	4.06	1.94	1D/4001	-35cm	No	Absent

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
65. Blade	10.94	5.73	2.05	1E/5002	-26cm	Yes	Whittle Wood
66. Blade	15.91	6.21	1.65	1E/5002	-26cm	Not Interpreted	PDSM
67. Blade	15.85	6.73	1.85	1E/5003	-33cm	No	Absent
68. Blade	12.86	7.54	2.01	1E/5003	-33cm	Yes	Whittle Wood
69. Blade	16.32	6.29	2.22	1E/5003	-33cm	No	Absent
70. Blade	17.13	9.28	2.06	1E/5003	-33cm	Yes	Whittle Wood
71. Blade	14.48	6.55	1.02	1E/5003	-33cm	No	Absent
72. Blade	9.37	2.99	1.8	1E/5003	-33cm	Yes	Cereal harvesting
73. Blade	7.81	5.13	1.73	1E/5003	-33cm	No	Absent
74. Blade	10.04	2.5	1.23	1E/5003	-33cm	Yes	Cereal harvesting
75. Blade	8.13	4.44	1.64	1E/5003	-33cm	No	Absent
76. Blade	10.43	3.18	1.52	1E/5004	-35cm	Yes	Cut roots and tubers
77. Blade	9.96	3.74	1.07	1E/5004	-41cm	No	Absent
78. Blade	9.84	6.22	1.52	1E/5004	-41cm	Yes	Cut roots and tubers
79. Blade	14.66	4.13	1.6	1E/5004	-41cm	No	Absent
80 Blade	22.98	6.78	2.76	1E/5004	-41cm	Not Interpreted	PDSM
81. Blade	14.69	6.26	1.57	1D/4003	-42cm	No	Absent
82. Blade	15.98	6.94	1.98	1E/5004	-41cm	No	Absent

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
83. Blade	16.92	7.21	2.58	1D/4002	-32cm	Yes	Longitudinal soft plant
84. Blade	18.58	4.98	2.34	1D/4002	-32cm	Yes	Scrape wet hide
85. Blade	15.44	6.42	2.28	1D/4002	-32cm	Not Interpreted	PDSM
86. Blade	12.29	4.09	1.21	1D/4003	-42cm	No	Absent
87. Blade	11.34	4.94	1.61	1D/4003	-42cm	Yes	Cut dry hide
88. Blade	13.21	6.27	1.9	1D/4003	-42cm	Yes	Whittle Wood
89. Blade	13.1	8.88	1.46	1D/4003	-42cm	Not Interpreted	PDSM
90. Blade	12.33	6.68	1.45	1D/4003	-42cm	Yes	Transverse soft animal
91. Blade	15.13	6.37	3.7	1D/4003	-42cm	Yes	Cutting soft plant
92. Blade	18.27	7.27	2.06	1D/4003	-42cm	No	Absent
93. Blade	12.11	4.7	1.02	1D/4003	-42cm	No	Absent
94. Blade	11.40	4.09	2.21	same	same	Not Interpreted	PDSM
95. Point	17.25	5.12	2.02	1C/3001	-32cm	Yes	Pierce hide
96. Point	16.11	4.44	1.9	1D/4001	-35cm	Yes	Pierce hide
97. Point	12.78	5.2	3.21	1D/4002	-32cm	Yes	Boring hard plant material
98. Point	14.12	3.53	1.33	1D/4003	-42cm	Yes	Pierce hide
99. Point	15.52	4.19	1.37	1D/4005	No depth	Yes	Boring hard plant material

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
100. Point	18.83	4.94	2.65	1A/1006	-45cm	Yes	Shoot animal
101. Point	8.47	3.65	3.17	1A/1006	-45cm	Yes	Pierce hide
102. Point	28.66	9.01	3.38	1A/1006	-45cm	Yes	Pierce hide
103. Point	12.41	3.65	1.75	1A/1006	-45cm	Yes	Pierce hide
104. Point	14	4.49	1.67	1B/2002	-23cm	Yes	Pierce Wood
105. Scraper	29.16	14.17	3.3	1E/5005	-41cm	Yes	Scrape dry hide
106. Scraper	17.97	14.63	4.35	1D/4003	-41cm	Yes	Scrape dry hide
107. Triangle	11.4	9.14	2.61	1A/1005	- 35 cm	Yes	Shoot animal
108. Triangle	11.43	2.57	1.16	1A/1005	- 35cm	Yes	Shoot animal
109. Triangle	20.84	6.85	2.77	1B/2006	- 40 cm	Yes	Shoot animal
110. Triangle	13.08	6.96	1.96	1E/5003	- 35 cm	Yes	Shoot animal
111. Triangle	13	7.7	1.32	1E/5003	- 35 cm	No	Absent
112. R. Flake	29.16	14.17	1.3	1E/5005	- 41 cm	Yes	Cut dry hide
113. R. Flake	13.16	5.14	1.76	1E/5005	- 41 cm	Yes	Meat/fish butchering
114. R .Flake	10.17	5.42	1.32	1C/3003	- 38 cm	Yes	Transverse soft animal
115. R. Flake	19.37	15.77	2.16	1C/3007	- 49 cm	Yes	Longitudinal hard animal
116. R. Flake	15.98	11.26	1.75	1A/1003	- 24 cm	Yes	Meat/Fish butchering
117. R. Flake	10.67	10.61	1.64	1A/1003	- 24 cm	Yes	Meat/Fish butchering

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
118. R. Flake	13.95	6.63	4.09	1A/1003	- 24 cm	No	Absent
119. R. Flake	10.07	6.59	1.22	1A/1003	-24 cm	Not Interpreted	PDSM
120. R. Flake	15.48	11.26	1.75	1A/1003	-24 cm	Yes	Whittle wood
121. R. Flake	14.95	10.82	2.77	1A/1006	- 45 cm	Yes	Scraping Roots and Tubers
122. R. Flake	6.53	7.17	2.55	1B/2010	No depth	Yes	Scrape dry hide
123. U. Flake	14.82	4.4	1.44	1A/1003	- 24 cm	Yes	Scrape dry hide
124. U. Flake	25.14	9.13	3.86	1A/1003	- 24 cm	Yes	Pierce soft animal
125. U. Flake	11.84	5.51	2.09	1A/1005	- 35cm	Unsure	Undetermined
126. U. Flake	14.02	4.25	2	1A/1005	- 35 cm	No	Absent
127. U. Flake	12.15	3.43	4.22	1A/1006	- 45 cm	Yes	Meat/Fish Butchering
128. U. Flake	8.24	1.71	4.57	1C/3003	- 38 cm	Yes	Pierce wood
129. U. Flake	10.87	5.4	1.44	1C/3004	No depth	No	Absent
130. U. Flake	7.34	6.95	1.08	1C/3005	- 43 cm	Unsure	Undetermined

APPENDIX D (CONTD.)

Tool Type	Length	Breadth	Thick	Trench/ Lot No.	Depth	Use	Activity
131. U. Flake	22.6	16.97	2.63	1D/4001	- 35 cm	Yes	Whittle Wood
132. U. Flake	16.76	7.86	1.59	1C/3003	- 38 cm	Yes	Meat/ Fish Butchering
133. U. Blade	15.81	3.4	1.79	1A/1003	-24 cm	No	Absent
134. U. Blade	10.82	4.48	1.73	1A/1003	- 24 cm	No	Absent
135. U. Blade	10.67	4.86	2.17	1A/1003	-24 cm	Yes	Scraping roots and tubers
136. U. Blade	11.85	3.69	1.85	1A/1005	- 35 cm	No	Absent
137. U. Blade	12.33	7.08	1.21	1A/1005	-35 cm	No	Absent
138. U. Blade	10.36	4.5	0.99	1B/2002	- 23 cm	No	Absent
139. U. Blade	13.7	4.44	1.67	1B/2002	- 23 cm	No	Absent
140. U. Blade	15.54	5.08	1.19	1B/2003	- 30 cm	Yes	Meat/Fish butchering
141. U. Blade	14.22	5.28	2.13	1B/2004	-30 cm	Yes	Whittle wood
142. U. Blade	16.33	5.59	2.86	1B/2005	-35 cm	No	Absent
143. U. Blade	14.97	6.35	1.29	1B/2008	- 43 cm	No	Absent

APPENDIX D (CONTD.)

144. U. Blade	11.63	5.46	0.86	1C/3001	- 32 cm	No	Absent
145. U. Blade	12.28	7.35	1.38	1C/3005	- 43 cm	No	Absent
146. U. Blade	15.56	8.07	1.86	1C/3005	- 43 cm	Yes	Multipurpose
147. U. Blade	11.01	4.51	2.21	1C/3007	- 49 cm	Yes	Whittle Wood
148. U. Blade	9.38	5.78	2.56	1D/4001	- 35 cm	Yes	Wood Work
149. U. Blade	16.42	10.7	2.14	1E/5002	- 26 cm	Not Interpreted	PDSM
150. U. Blade	10.89	13.73	4.29	1E/5003	-33 cm	Yes	Meat/Fish butchering

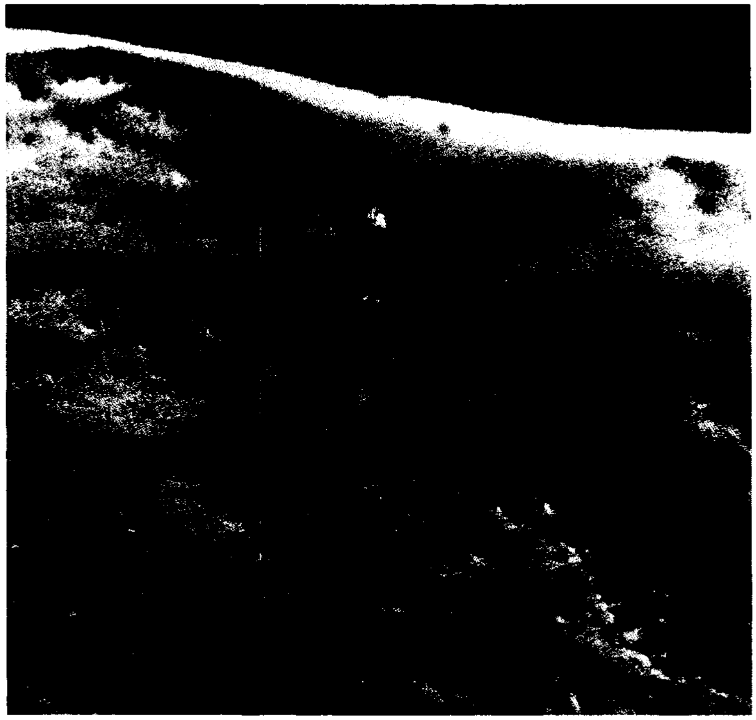

Figure 30: Polish from Cutting Cereal (artifact no. 6, 400X)

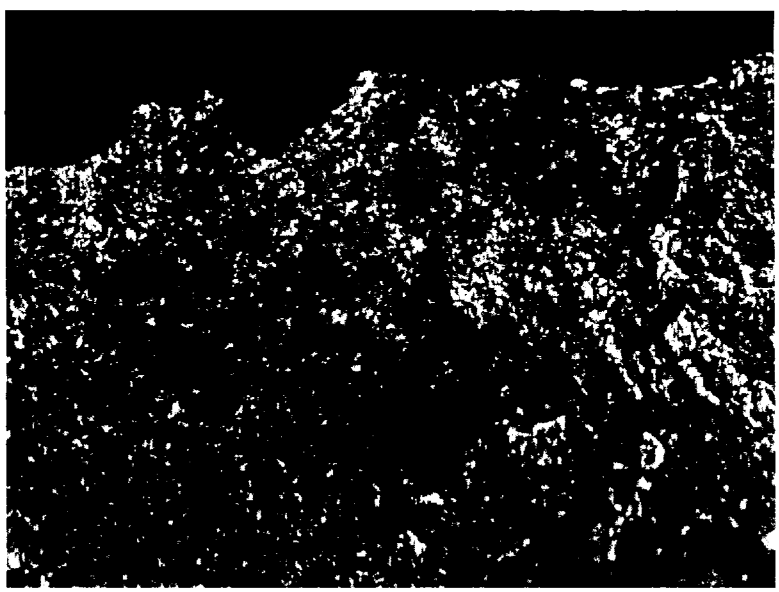

Figure 31: Wear Traces from Butchering Meat/Fish (artifact no. 47 300X)

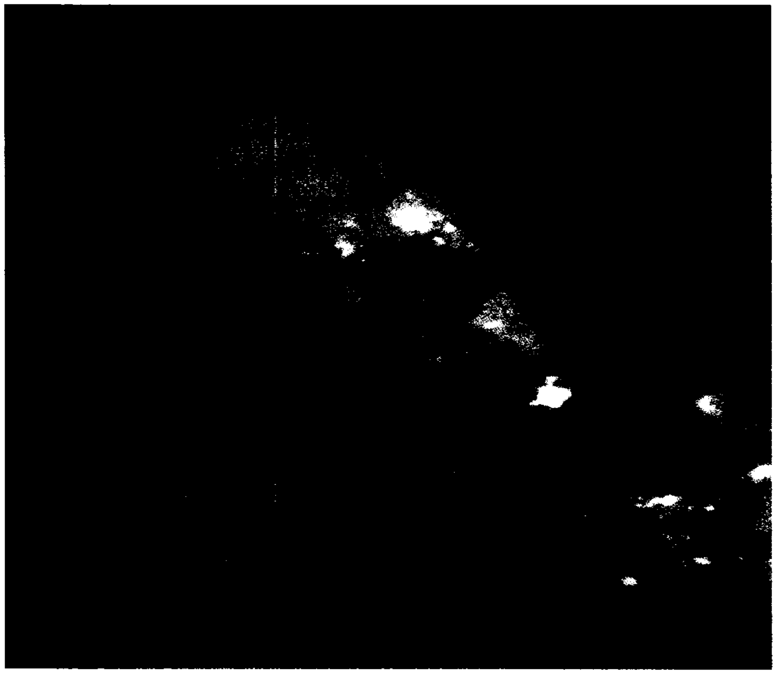

Figure 32: Metallic Polish from Cutting Dry Reed (artifact no. 52, 300X)

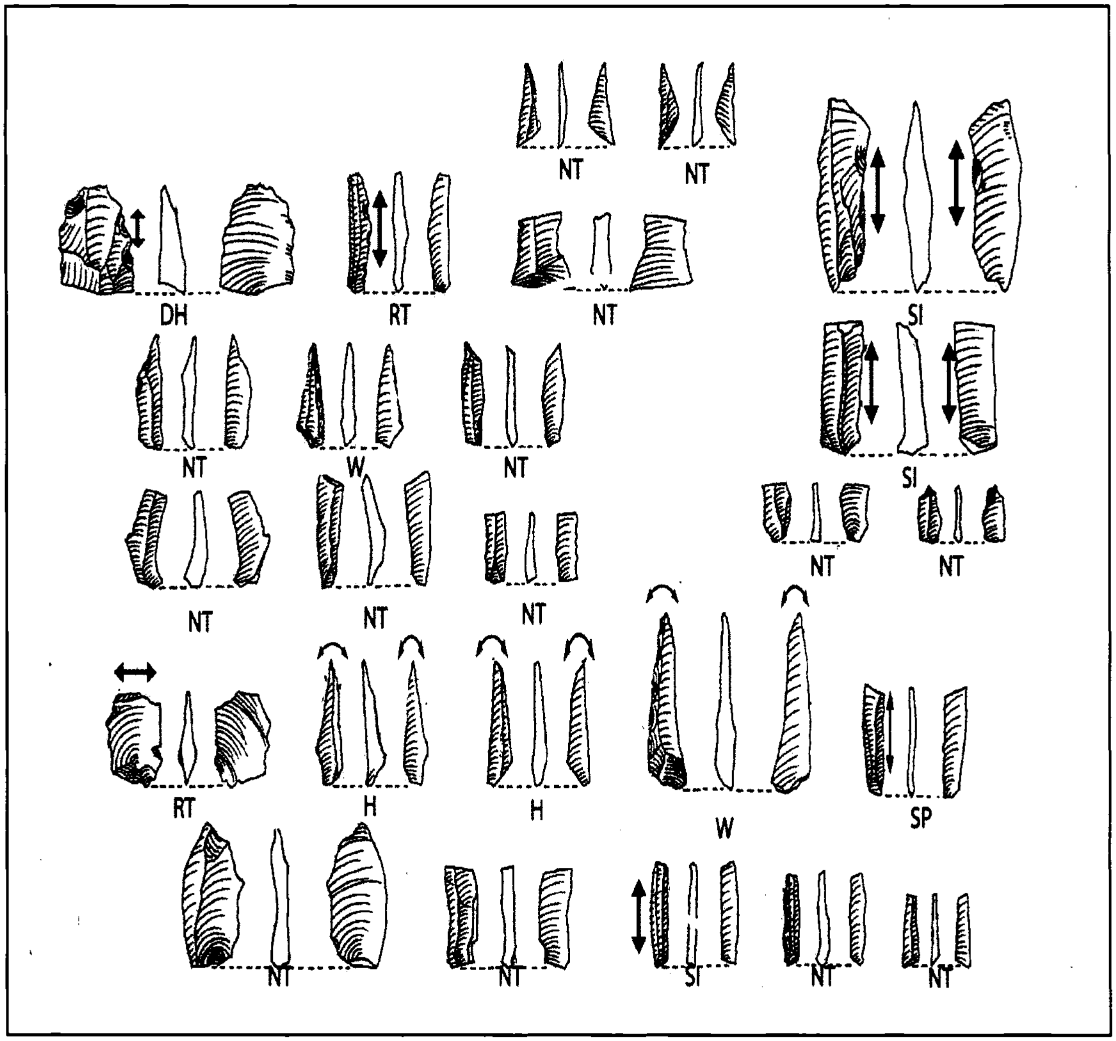

Figure 33: Ceramic Phase Artifacts Studied for Use-Wear

APPENDIX E

MODERN PLANTS STUDIED

This appendix includes the starchy plant foods utilized in Rajasthan in the present and some other comparative material. These plants were used as a modern reference collection and comparative material to study the archaeological samples from Bagor.

Local Name	Scientific Name	Genus	Species	Passport
1. Cyperus (Motha)	Cyperus rotundus L.	Cyperus	Rotundus	Gilund, Rajasthan
2. Date (Khajoor)	Phoenix dactylifera/ sylvestris (L.) Roxb.	Phoenix	sylvestris	Gilund, Rajasthan
3. Sesame (Til)	Sesamum indicum	Sesamum	Indicum	Gilund, Rajasthan
4. Bean (Moong)	Vigna mungo	Vigna	Mungo	Indian Grocery, Delaware
5. Bean (Urad)	Vigna radiata	Vigna	Radiate	Whole Foods Market/ D. C.
6. Gram (Liluah)	Vigna radiata sublobata	Vigna	sublobata	Gilund, Rajasthan
7. Lentil (Masur)	Lens culinaris	Lens	Culinaris	Gilund, Rajasthan
8. Pigeon Pea (Toor)	Cajanus cajan L.	Cajanus	Cajan	Indian Grocery, Delaware
9. Val (Hyacinth Beans)	Lablab purpureus	Lablab	purpureus	Indian Grocery, Delaware
10. Bean (Moth)	Vigna aconitifolia	Vigna	aconitifolia	Indian Grocery, Delaware
11. Horse gram	Macrotyloma uniflorum	Macrotylo ma	uniflorum	Gilund, Rajasthan
12. Sorghum (Jowar)	Sorghum bicolor L.	Sorghum	bicolor	Indian Grocery, Delaware
13. Finger millet (Ragi)	Eleusine coracan L.	Eluecine	coracana	Indian Grocery, Delaware

APPENDIX E (CONTD.)

Local Name	Scientific Name	Genus	Species	Passport
14. Pearl Millet (Bajra)	Pennisetum glaucum	Pennisetum	glaucum	Indian Grocery, Delaware
15. (Ajwain/Jawain)	Trachyspermum ammi (L.)	Trachyspermum	ammi	Gilund, Rajasthan
16. Rice (Chawal)	Oryza sativa	Oryza	sativa	Gilund, Rajasthan
17. Wheat (Aatta)	Triticum aestivum	Triticum	aestivum	Gilund, Rajasthan
18. Barley	Hordeum vulgare	Hordeum	vulgare	Whole Foods Market, D.C.
19. Sweet Potato Shakarkand	Ipomoea batatas	Ipomoea	batatas	Gilund, Rajasthan
20. Ginger (Adarakh)	Zingiber officinale Rosc.	Zingiber	officinale	Indian Grocery, Delaware
21. Yam (Suran)	Amorphophallus campanulatus	Amorphophallus	campanulatus	Gilund, Rajasthan
22. Taro Arvi	Colocassia esculenta	Colocassia	esculenta	Gilund, Rajasthan
23. Lotus (Sanghre)	Nymphaea lotus L.	Nymphaea	lotus	Udaipur, Rajasthan
24. Chick Peas (Chana)	Cicer arietinum L.			Whole Foods Market, D.C.
25. Jujube (Bor)	Zizyphus jujube	Zizyphus	jujube	Gilund, Rajasthan
26. Galanga	Kaempferia galang	Kaempferia	galanga	H. Mart, D.C.
27. Mango (Aam)	Mangifera	Mangifera		Whole Foods Market, D. C.
28. Turmeric (Haldi)	Curcuma longa	Curcuma	longa	H Mart, D. C.
29. Indian Egg plant (Baingan)	Solanum			H Mart, D.C.
30. Tamarind (Imli)	Tamarindus indica L.	Tamarindus	indica	Grocery, Virginia
31. Mustard (Sarso)				

APPENDIX F

CHARACTERISTIC FEATURES AND PHOTOGRAPHS OF STARCHES FROM MODERN PLANTS (All pictures are 20 μm unless mentioned otherwise)

Scientific Name	Size	Description
Cyperus rotundus L. or, *Motha* (Figure 34.1–34.4)	Varies from – 13.42 – 62.78μm, Average – 32.38μm	Three shapes –sphere, oval and angular (almost squarish) are present. The hilum when seen is eccentric. Lamellae are present -- varies from faint to very faint. The extinction cross is very prominent
Phoenix dactylifera/ sylvestris (L.) Roxb. or, Date (Figure 35.1–35.4)	Varies from – 3.37 – 26.45μm Average – 11.01μm	Two shapes are prominent –sphere and oval. Hilum is in the center and is open. It goes in and out on fine focus. Lamellae are absent. There are two lines on the edge and there is light emanating between the two lines under polarized light. In three dimensions there is a mesial longitudinal line in the center. On rotation the hemisphere ones have a prominent depression in the center while ovoids are raised in the center. There is a crease observed on the grains on rotation.
Sesamum indicum or sesame (Figure 36.1-36.2)	Varies from – 5.06 – 14.88μm Average – 10.02μm	Compound grains, polygonal in shape. The edges of sesame unlike those of rice are more rounded. The grains have a centric hilum; the center looks grayish, there are demonstrable lamellae in the center which makes it look like a depression in the center. The grains rotate like a ball when turned and in three dimension look disc shaped.
Vigna mungo or Moong Beans (Figure 37.1–37.3)	Varies from Length = 8.41- 32.31μm, Width = 8.41 - 23.68μm Average Length – 18.56μm Average Width – 14.80μm	Starch grains are spherical and ovoid/elongate in shape. Some of the grains when turned look angular. The starches have a dull luster (even under polarized light and light emanates from only where the fissures are). Lamellae are prominent but more on the edges than in the center. Fissures are present. They extends longitudinally in the elongate grains, some of the grains have depression in the center. The hemispherical (average size 13.89μm) ones have fissures which extend all over the grain and they give a v shaped appearance.

Figure 34.1: Oval Starches from *Cyperus rotundus*

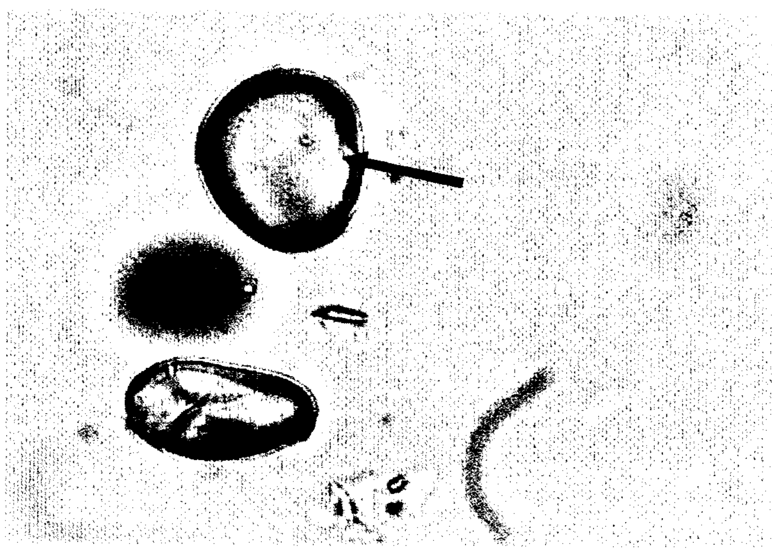

Figure 34.2: Eccentric hilum in *Cyperus rotundus*

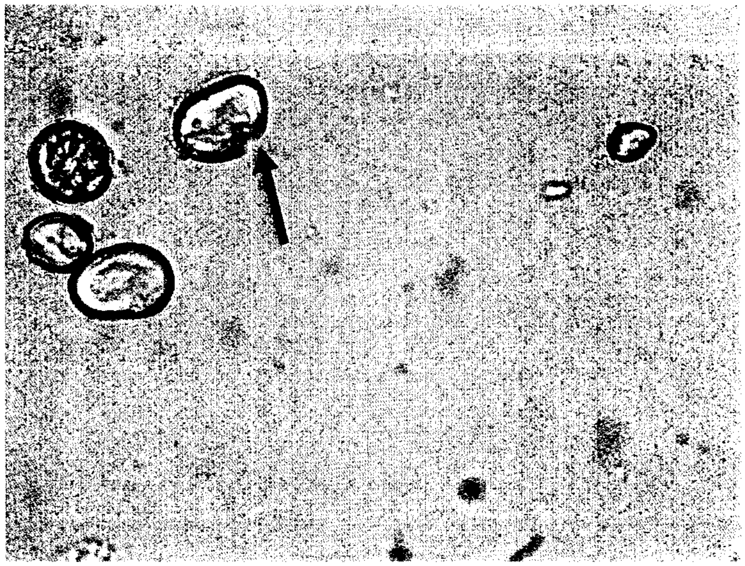

Figure 34.3: Damaged Starches from *Cyperus rotundus*

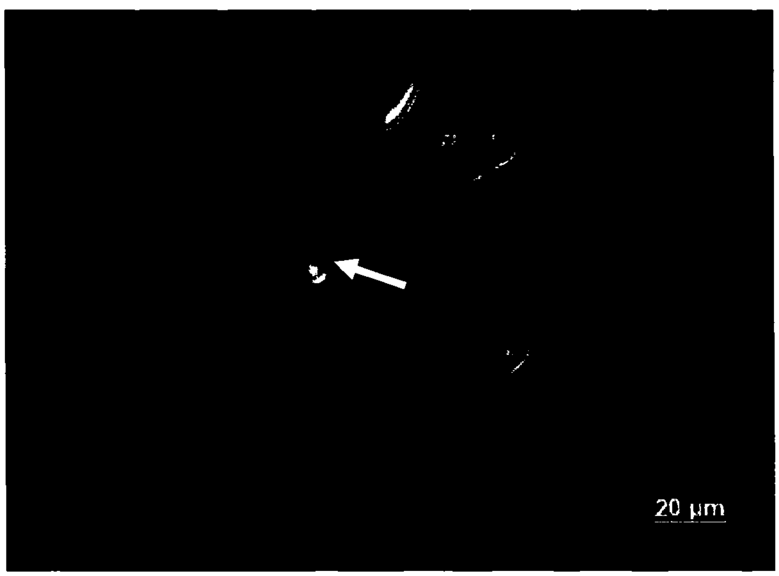

Figure 34.4: Prominent Extinction Cross of *Cyperus rotundus* (under polarize light)

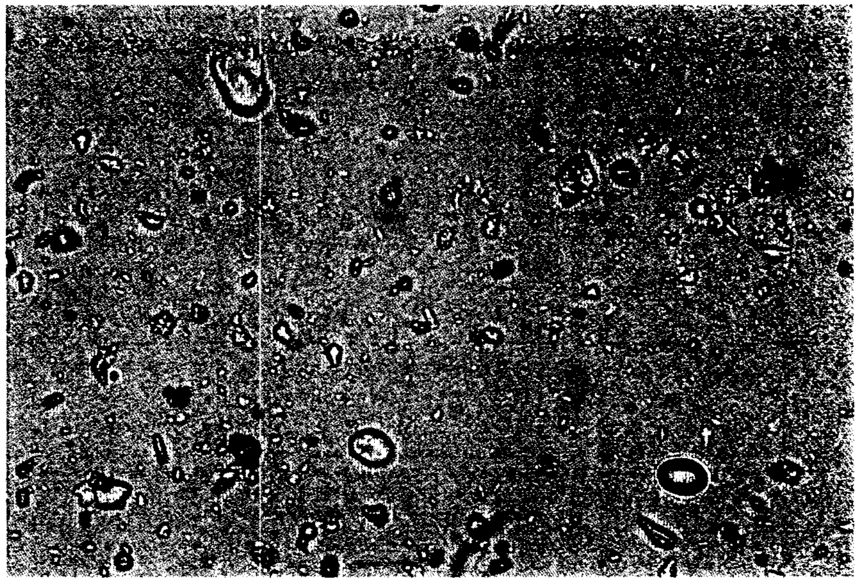

Figure 35.1: Elongate Starches from *Phoenix dactylifera*

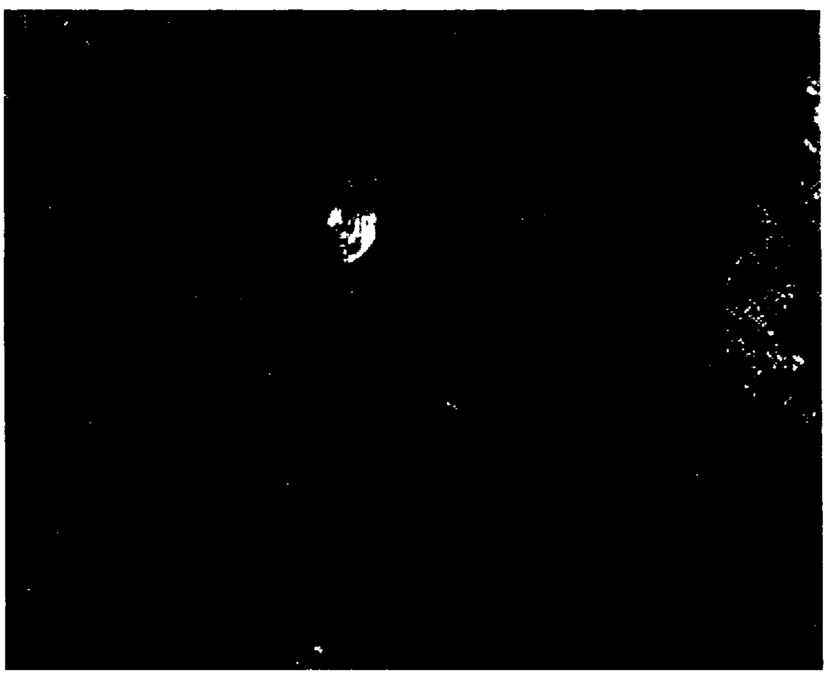

Figure 35.2: *Phoenix dactylifera* starches (under polarize light)

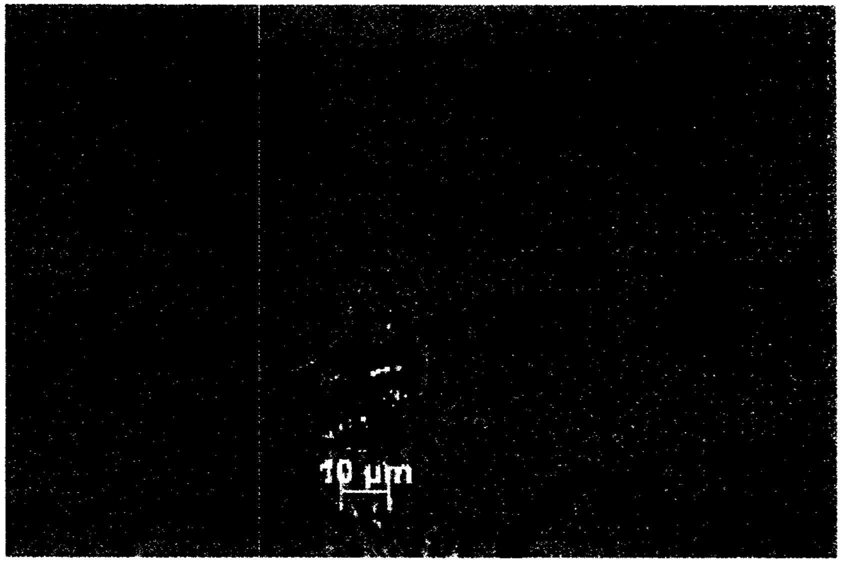

Figure 35.3: Spherical Starches from *Phoenix dactylifera*

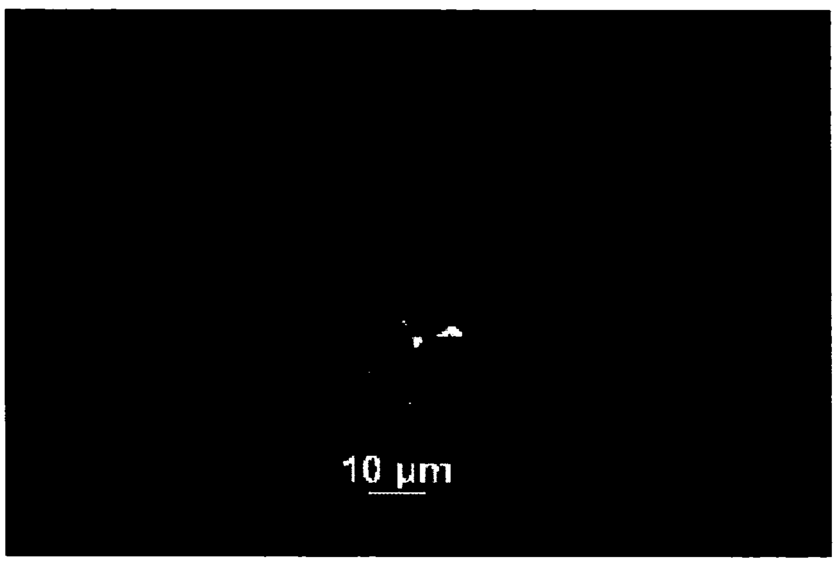

Figure 35.4: Spherical Starches from *Phoenix dactylifera*

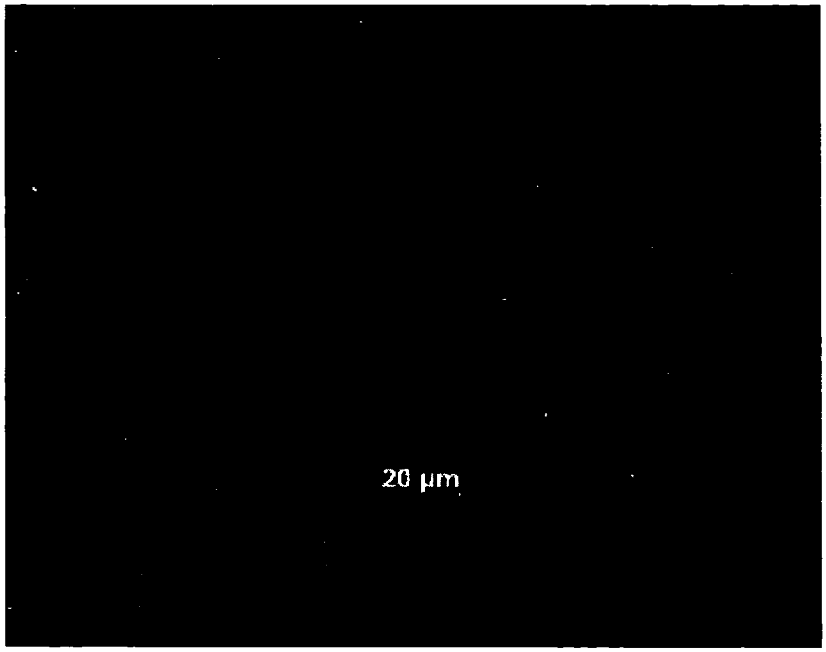

Figure 36.1: Compound Starches from *Sesame indicus*

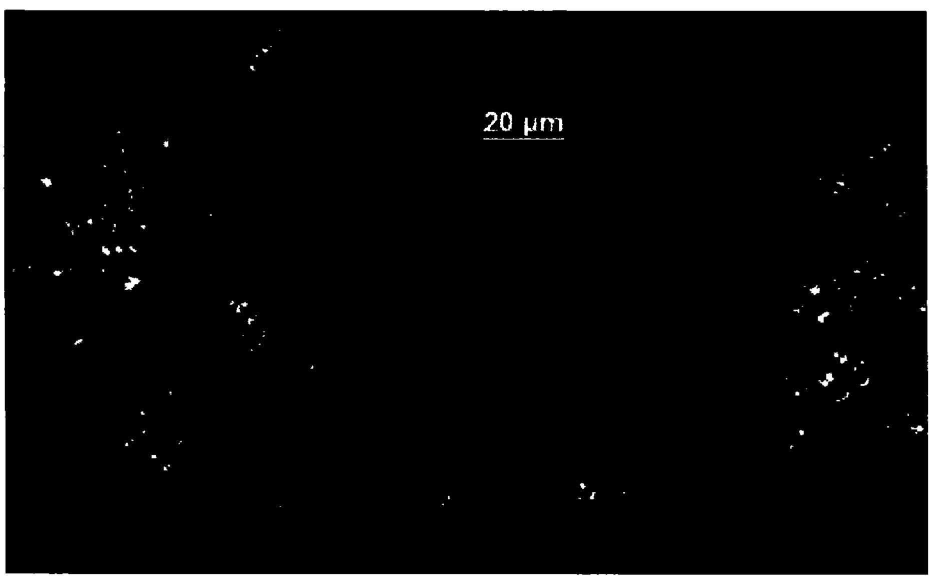

Figure 36.2: Starches from *Sesame indicus* (under polarize light)

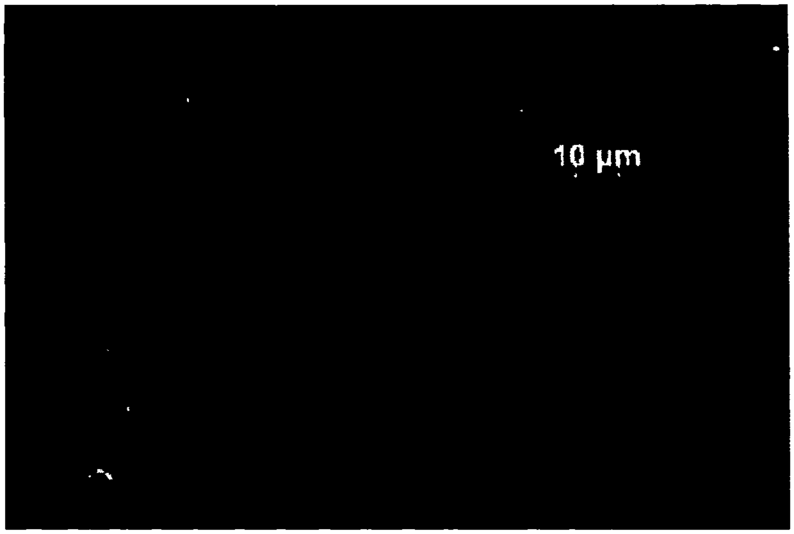

Figure 37.1: Elongate and Spherical Starches from *Vigna mungo*

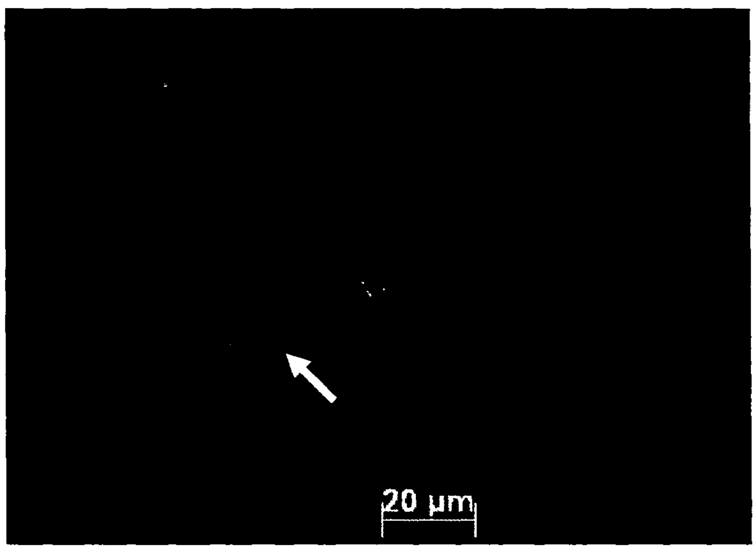

Figure 37.2: Prominent Fissures in *Vigna mungo*

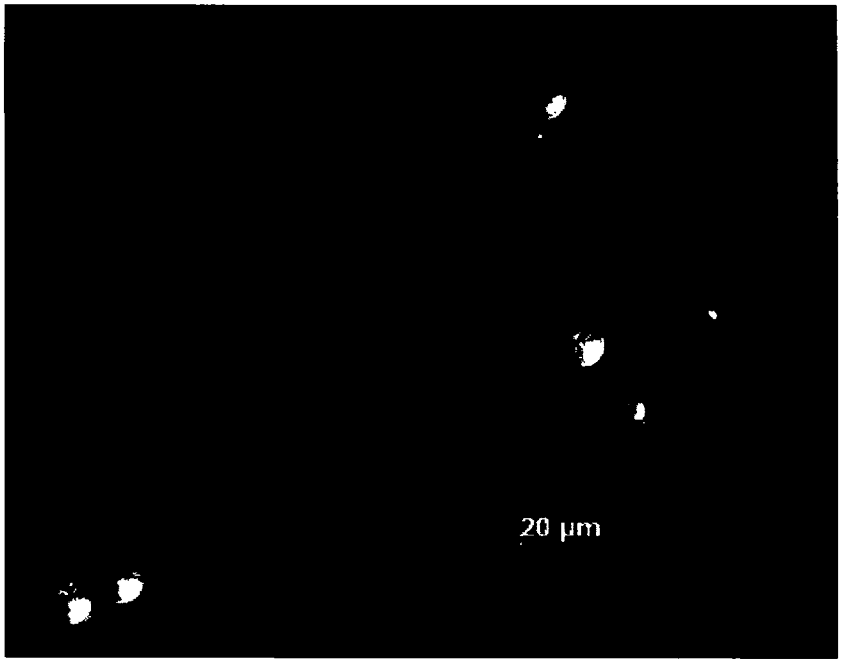

Figure 37.3: Characteristics of *Vigna mungo* (under polarize light)

APPENDIX F (CONTD.)

Scientific Name	Size	Description
Vigna radiata or Urd Bean (Figure 38.1–38.4)	Varies from Length = 7.86 – 34.34μm, Width = 7.86 – 19.32μm Average Length – 19.35μm Average Width – 15.17μm	Starch grains are spherical and ovoid/elongate in shape. The starches have a bright look. Lamellae are prominent. Fissures are present and extend longitudinally. The round (average size 13.95μm) ones have fissures also. In general the starches are brighter and slightly bigger than the *Vigna mungo*. One of the characteristic feature of the starches especially the hemispherical ones is that the hilum is in the center and in form of a raised point (looks like an orange) and a band or two surrounds it.
Vigna radiata sublobata or Gram (Figure 39.1–39.4)	Varies from – 6.44 – 31.23μm Average – 19.22μm	Very similar to *Vigna radiata* except there is a bright band around the edge under polarized light
Lens culinaris or Masur Lentils (Figure 40.1–40.4)	Varies from – 10.30 – 37.7μm Average – 22.9μm	Ovoid and spherical grains. Lamellae are very, very pronounced (more than the Vigna spp.). The fissures are very deep. They run all across the length of the grain and divide the grain into two halves (looks like a hot dog). Under polarize light— the grains look very bright with light radiating and in a few extinction cross is visible.
Macrotyloma uniflorum or Horse Gram (Figure 41.1–41.6)	Varies from – Length =12.57 – 52.51μm, Width = 12.54 – 31.75μm Average Length – 30.84μm Average Width – 20.98μm	Grains are spherical and elongate in shape and very dull looking. There is band along the edge. The grains are also wide and on rotation one side is bulkier. The grains are the large and very wide. Some of the hemispherical grains (average size 16.30μm) have cross shaped fissures and they rotate like balls. Fissures are present and they look like a river with branches but the fissures seldom extend longitudinally throughout the grain. Lamellae are very prominent.

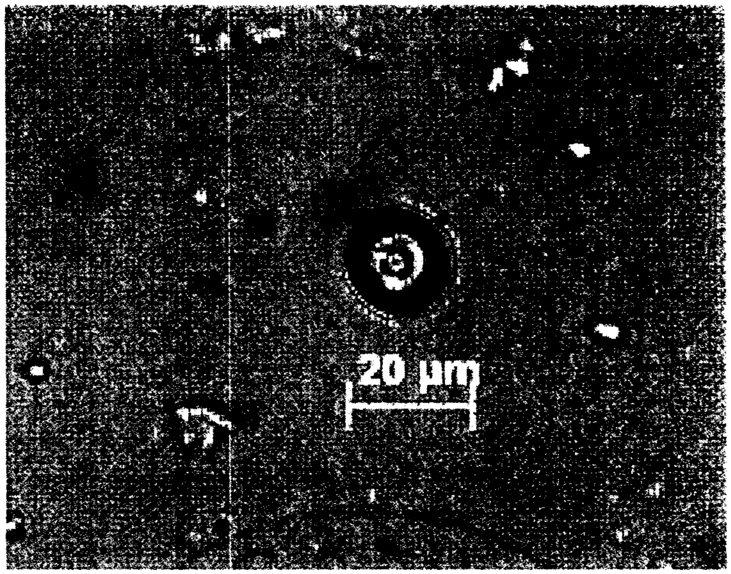

Figure 38.1: Spherical Starch from *Vigna radiata*

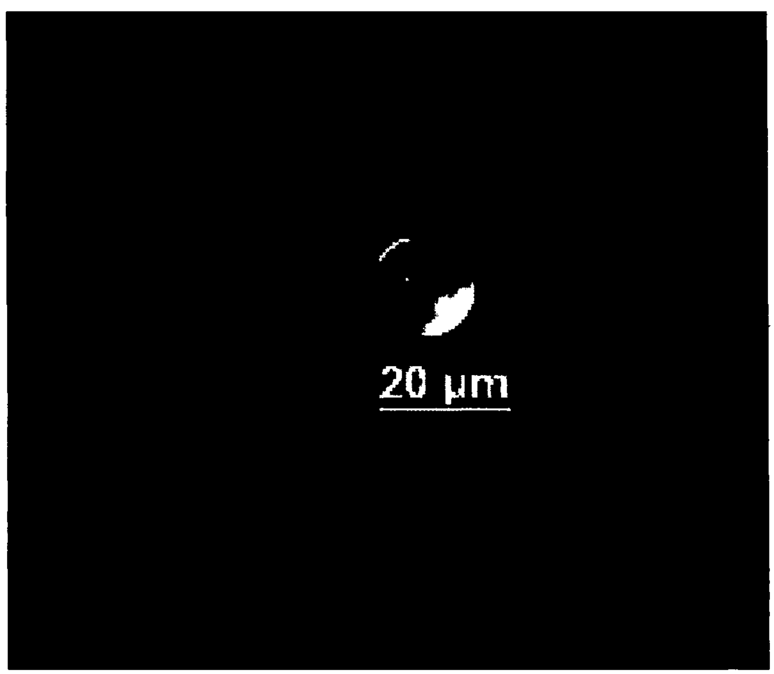

Figure 38.2: Spherical Starch from *Vigna radiata* (under polarize light)

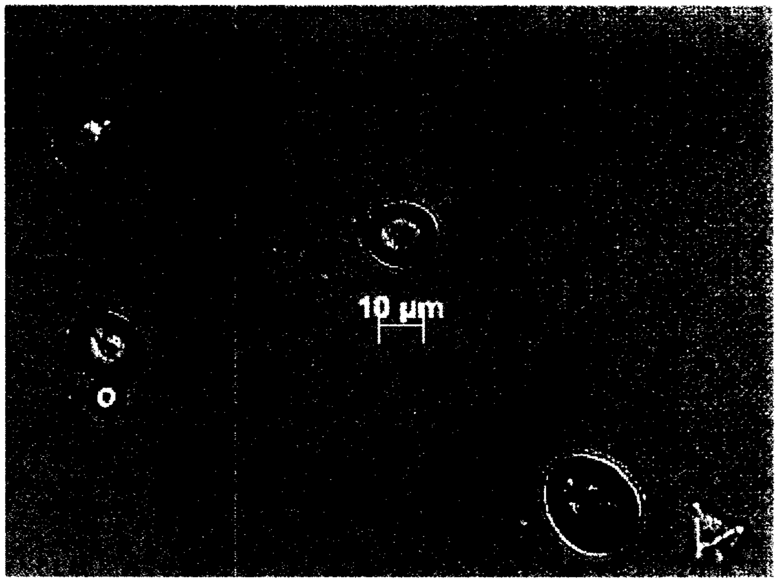

Figure 38.3: Spherical and Elongate Starch from *Vigna radiata*

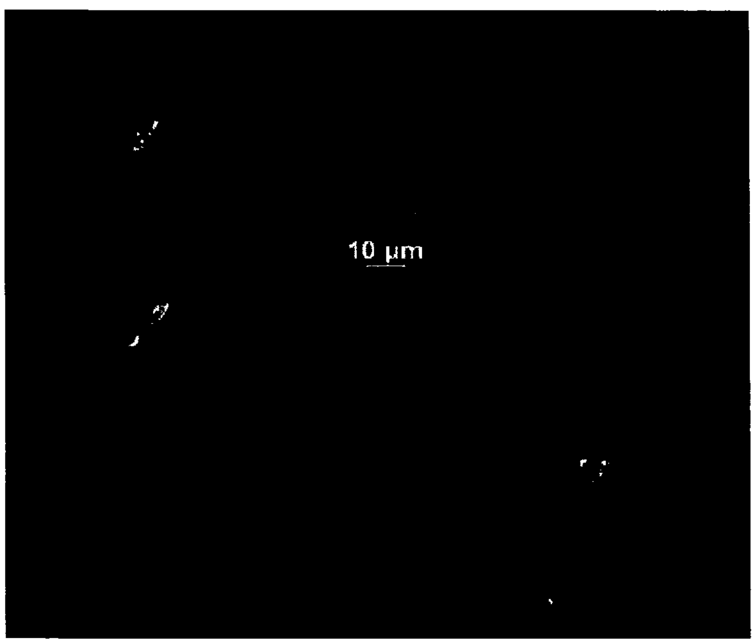

Figure 38.4: Spherical and Elongate Starch from *Vigna radiata* (under polarize light)

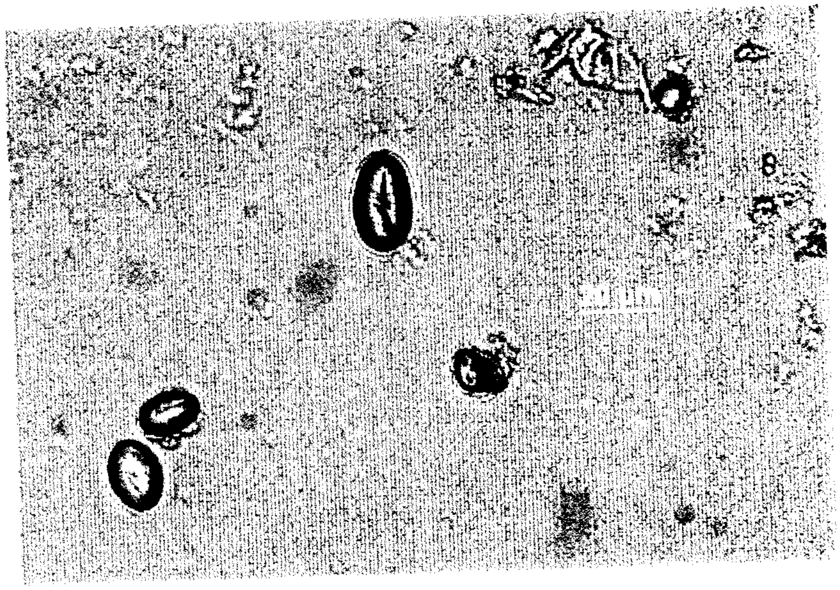

Figure 39.1: Elongate Starches from *Vigna radiata sublotata*

Figure 39.2: Elongate Starches from *Vigna radiata sublotata* (under polarize light)

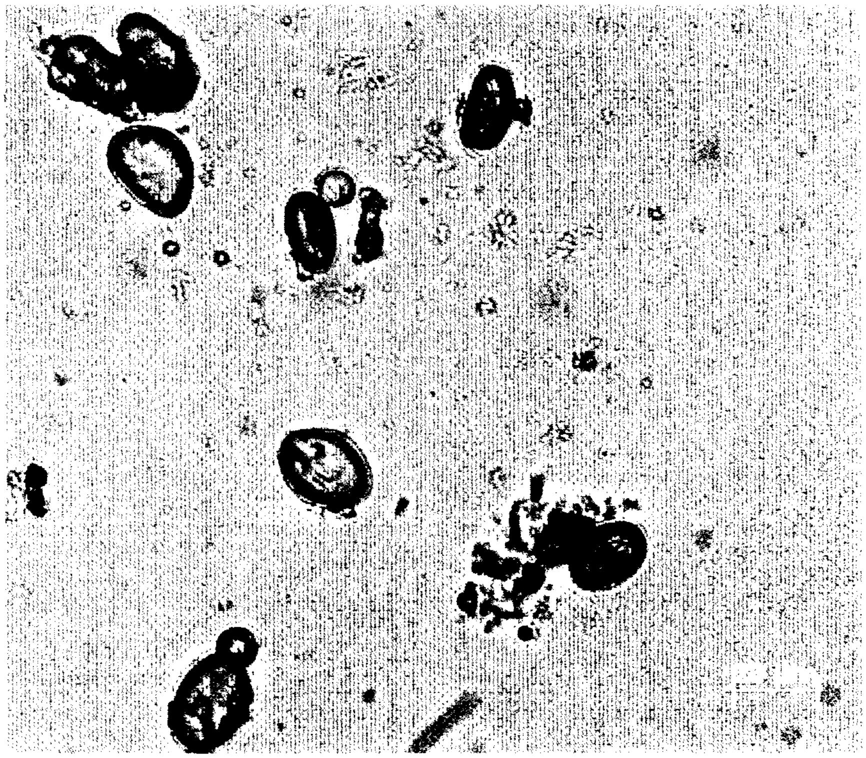

Figure 39.3: Damaged Elongate Starches from *Vigna radiata sublotata*

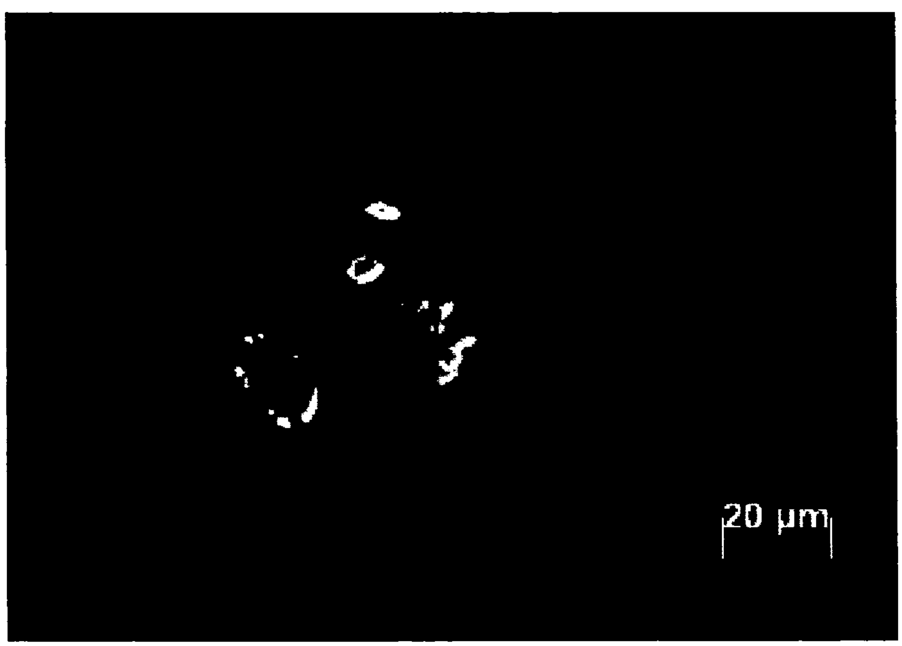

Figure 39.4: Damaged Elongate Starches from *Vigna radiata sublotata* (under polarize light)

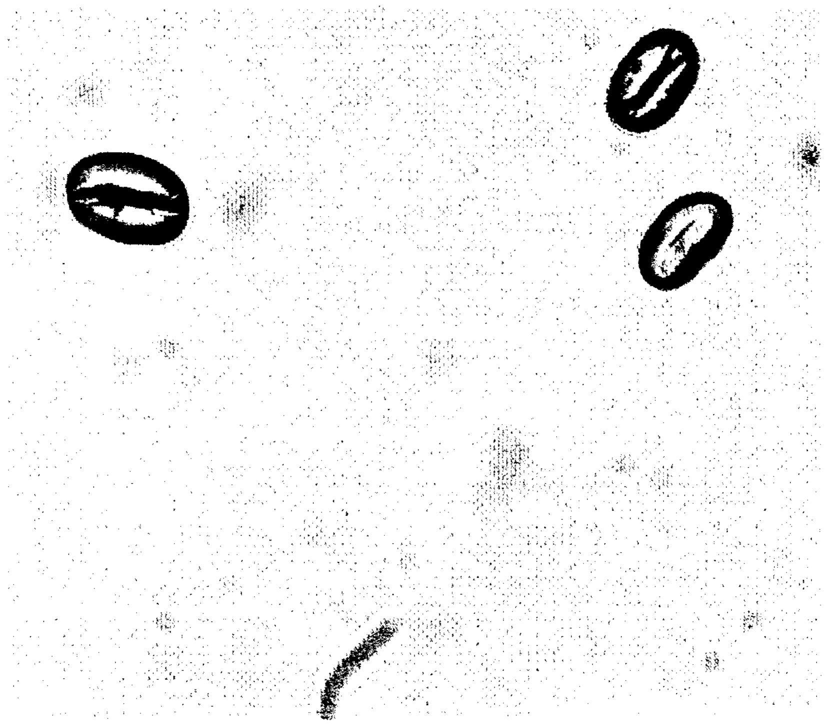

Figure 40.1: Elongate Starches from *Lens culinaris*

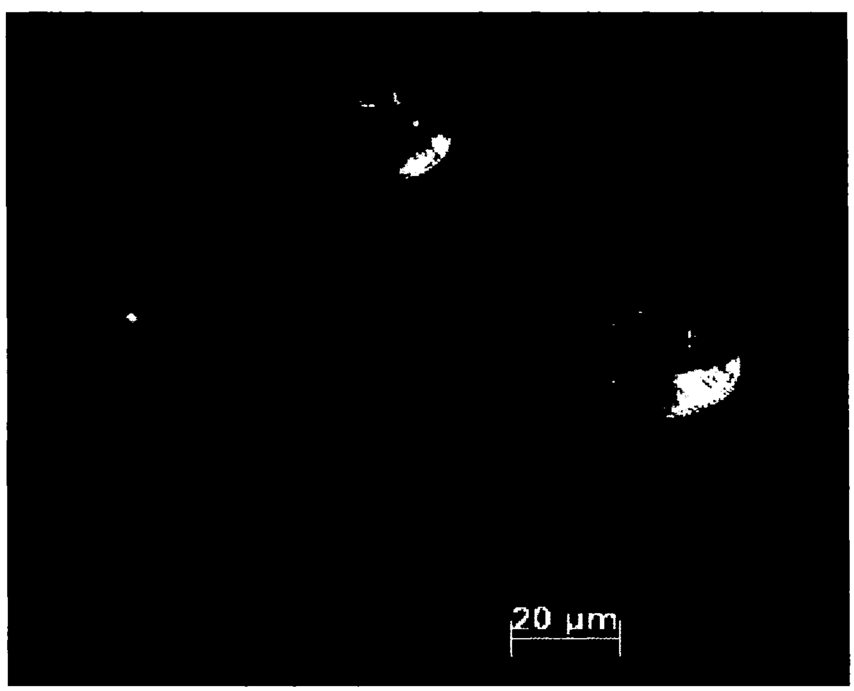

Figure 40.2: Elongate Starches from *Lens culinaris* (under polarize light)

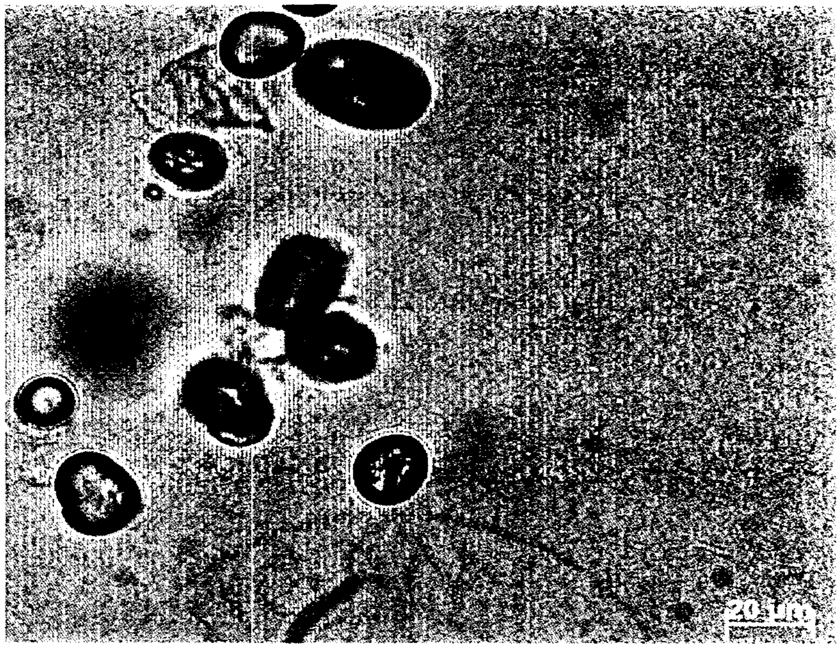

Figure 40.3: Elongate and Spherical Starches from *Lens culinaris*

Figure 40.4: Elongate and Spherical Starches from *Lens culinaris* (under polarize light)

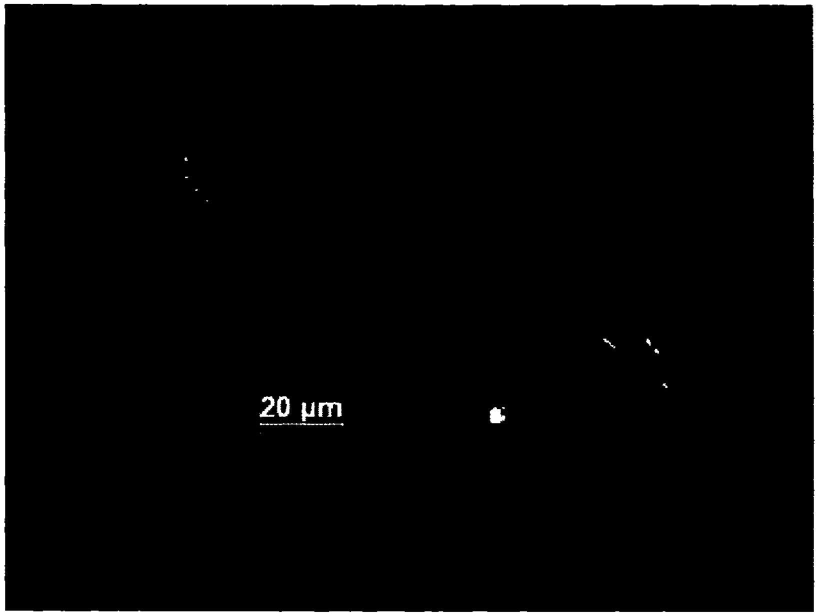

Figure 41.1: Elongate Starches from *Macrotyloma uniflorum*

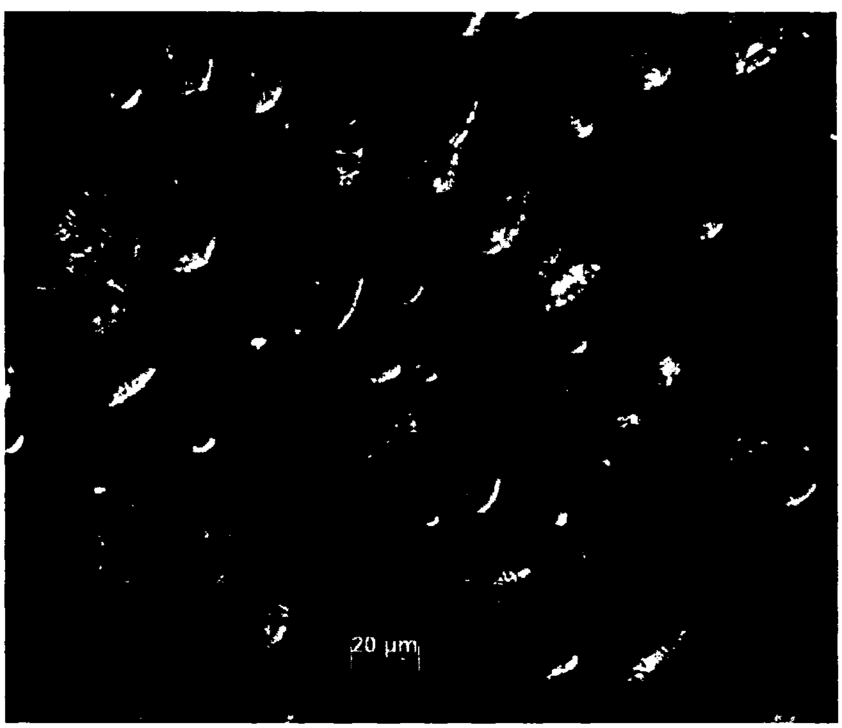

Figure 41.2: Elongate Starches from *Macrotyloma uniflorum* (under polarize light)

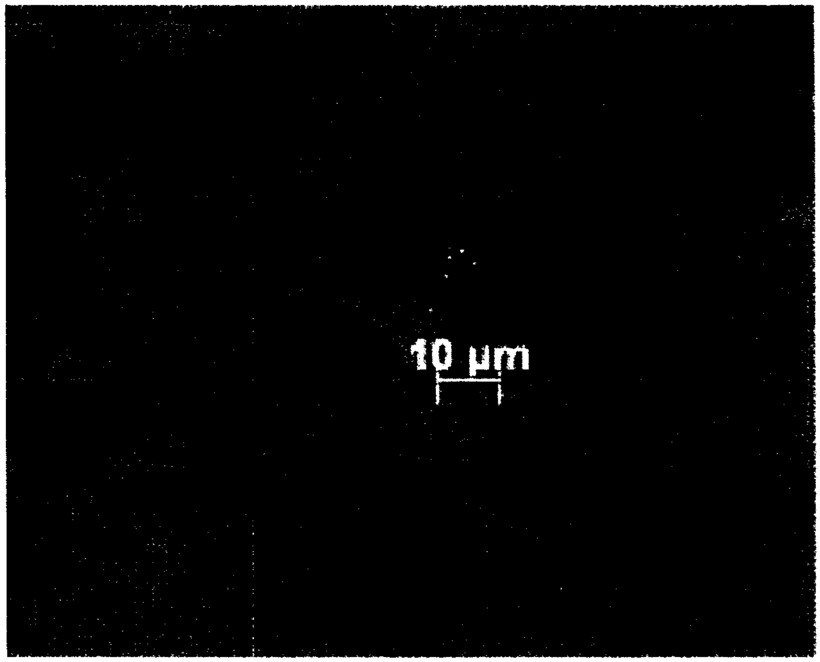

Figure 41.3: Spherical Starches from *Macrotyloma uniflorum* with stellate hilum

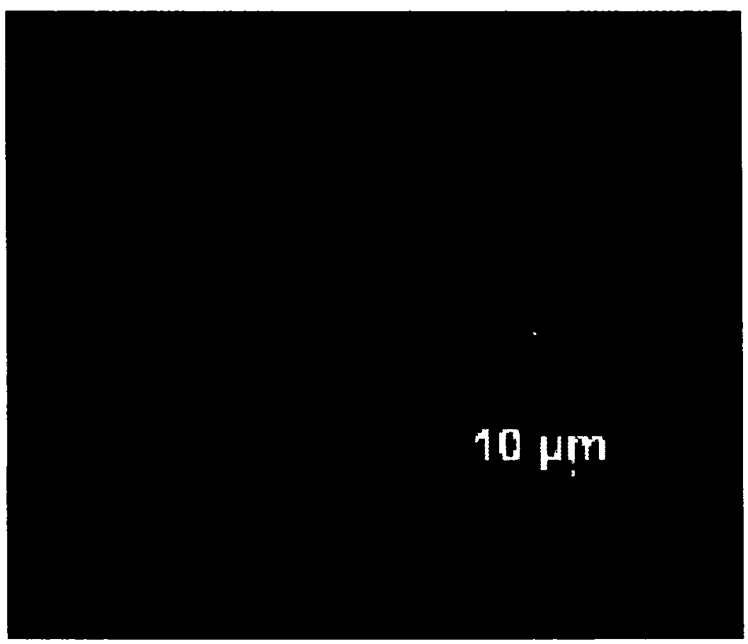

Figure 41.4: Spherical Starches from *Macrotyloma uniflorum* (under polarize light)

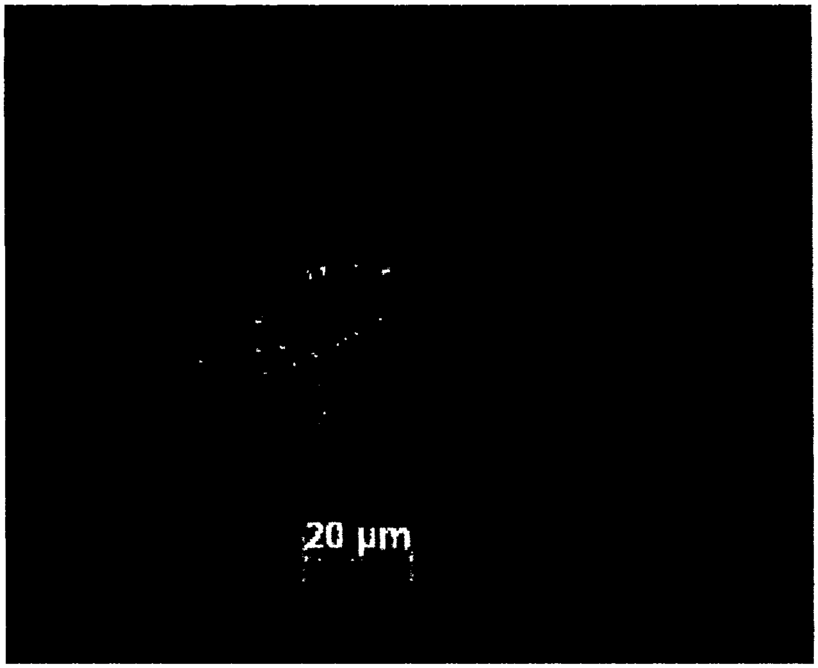

Figure 41.5: Damaged Spherical Starches from *Macrotyloma uniflorum*

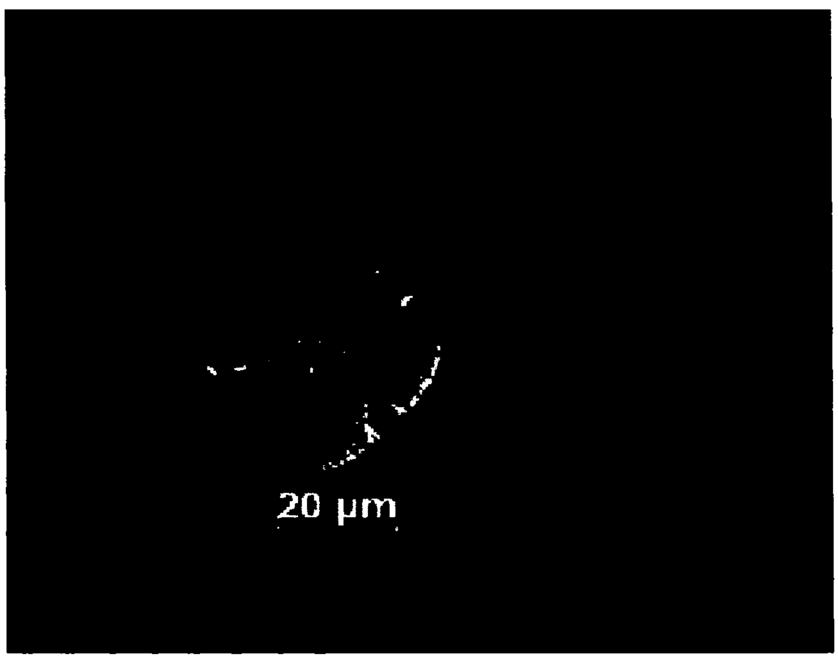

Figure 41.6: Damaged Spherical Starches from *Macrotyloma uniflorum* (under polarize light)

APPENDIX F (CONTD.)

Scientific Name	Size	Description
Lablab purpureus or Hyacinth Beans (Figure 42.1– 42.2)	Varies from – Length = 11.72 – 34.3µm, Width =11.72 – 24.28µm Average Length – 23.14µm Average Width – 17.39µm	Grains are elongate and spherical. The fissures are in form of a straight line they are not deep as in *Macrotyloma uniflorum*). Centric hilum seen in some hemispheres. A very distinct extinction cross present under polarize light, which divides the hemisphere grains into four halves and elongate grains into two. Lamellae are present towards the center more.
Vigna aconitifolia or Moth Beans (Figure 43.1–43.2)	Varies from – Length =12.3 – 44.4 µm, Width = 9.97 – 30.31µm Average Length – 26.25µm Average Width – 18.58µm	Grains are elongate and spherical. The grains are big and also wide. Fissures are present and look like rivers with branches. They run through out the grains. Looks like a mix between *Lens culinaris* and *Macrotyloma uniflorum* but much larger than Lens and the fissures unlike the Macrotyloma have a raised lip like appearance.
Cajanus cajan L. or Pigeon Pea (Figure 44.1–44.3)	Varies from – Length =19.11 – 48.52µm, Width = 16.09 – 39.05µm Average Length – 32.8µm Average Width – 24.5µm	Grains are spherical and elongate in shape and very bright looking (unlike Macrotyloma which is very dull). There is band along the edge which is more prominent in polarize light. The grains are big and also wide (even bigger than Macrotyloma). The grains have fissures. Fissures are present on almost all the grains but they are both latitudinal and longitudinal. The fissures are very, very deep. Lamellae are very prominent.
Hordeum vulgare or Barley (Figure 45.1–45.2)	Varies from – 18 – 26µm	Grains are simple and circular to oval. In three dimensions they look more lenticular. Hilum is centric. Lamellae are present. The grains have a deep crater like appearance and resembling the cells of a beehive.

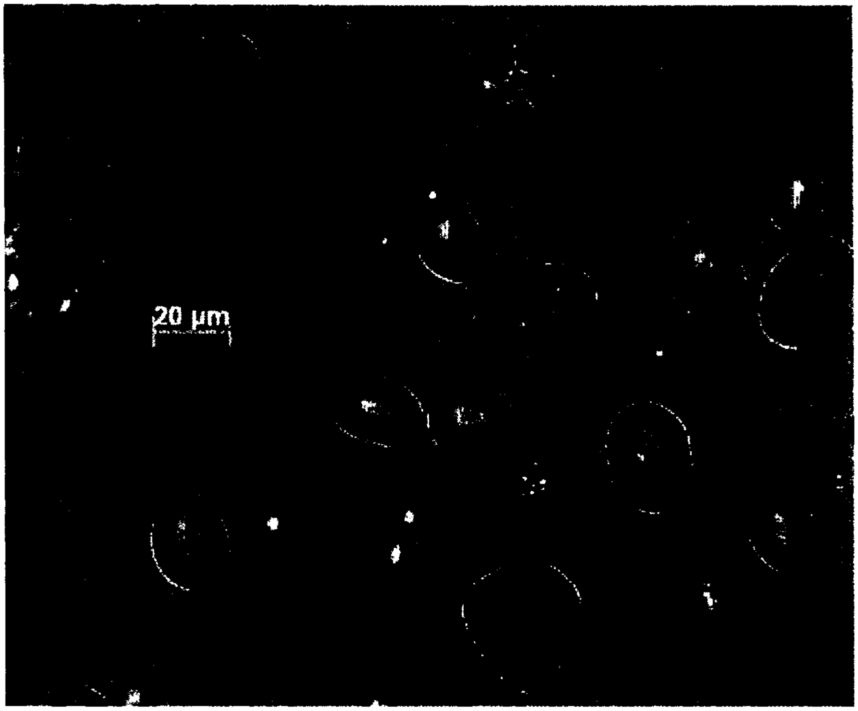

Figure 42.1: Elongate and Spherical Starches from *Lablab purpureus*

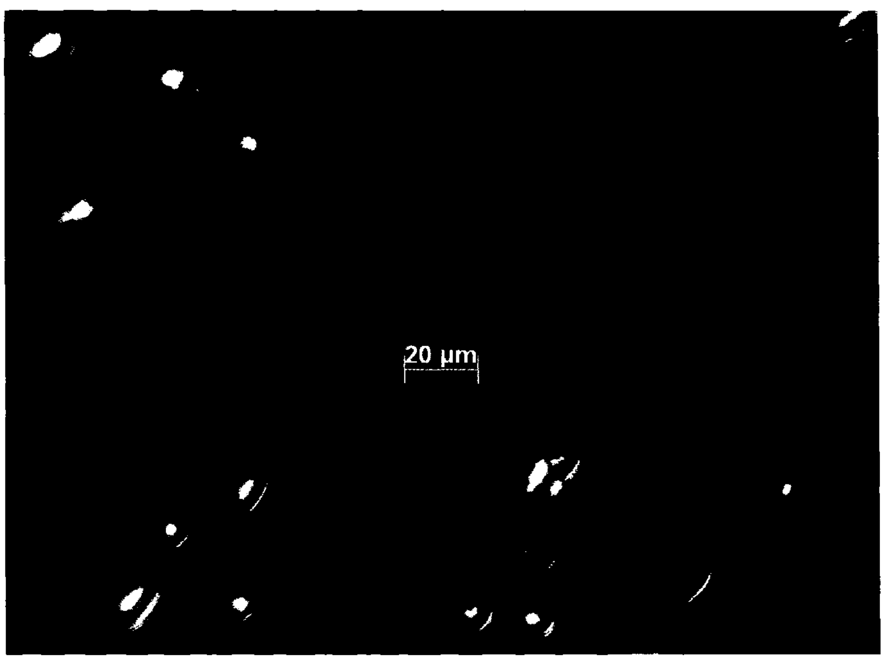

Figure 42.2: Elongate and Spherical Starches from *Lablab purpureus* (under polarize light)

Figure 43.1: Elongate Starches from *Vigna aconitifolia*

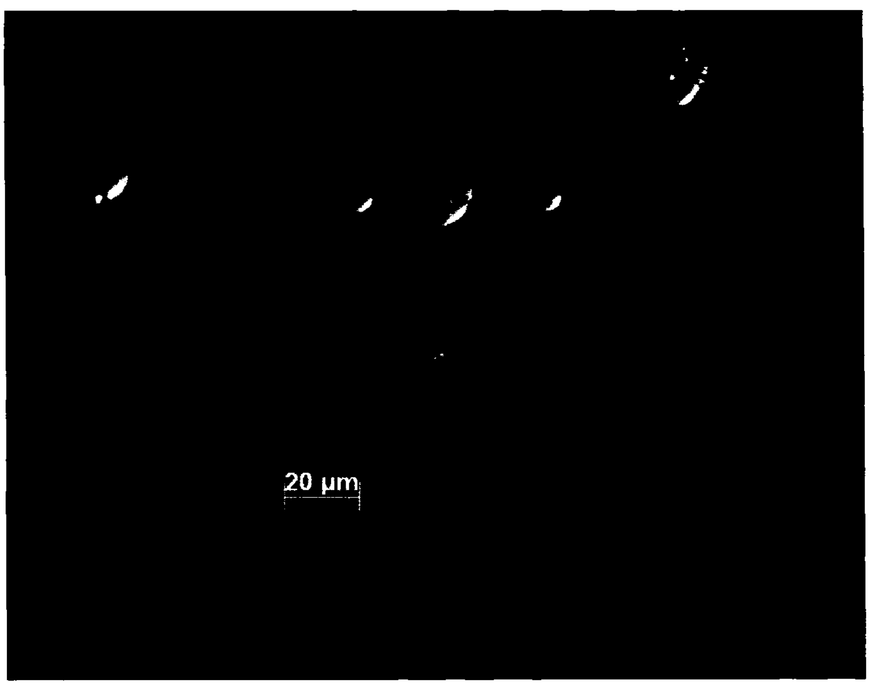

Figure 43.2: Elongate Starches from *Vigna aconitifolia* (under polarize light)

Figure 44.1: Elongate and Spherical Starches with concentric layers from *Cajanus cajun*

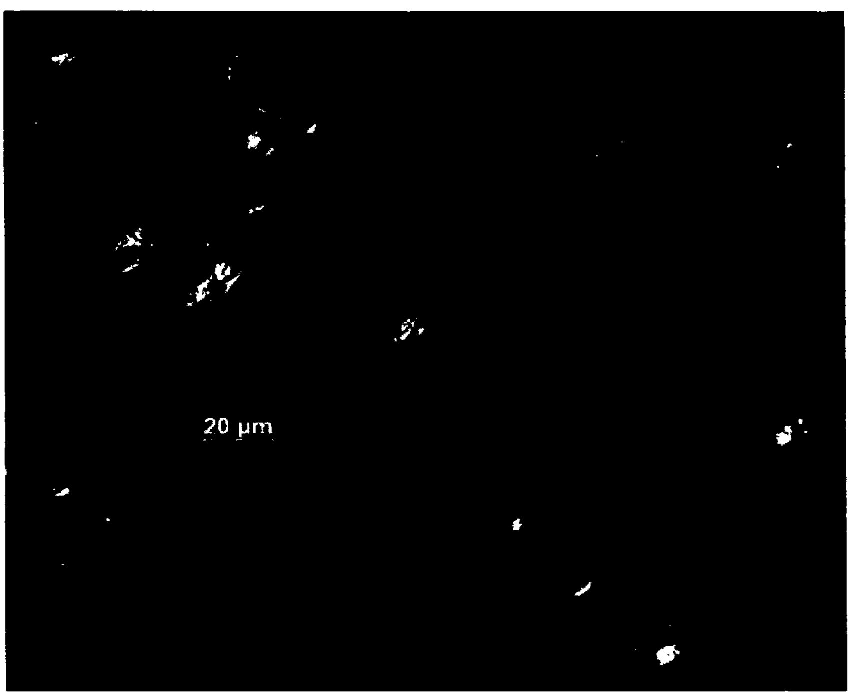

Figure 44.2: Elongate and Spherical Starches from *Cajanus Cajun* (under polarize light)

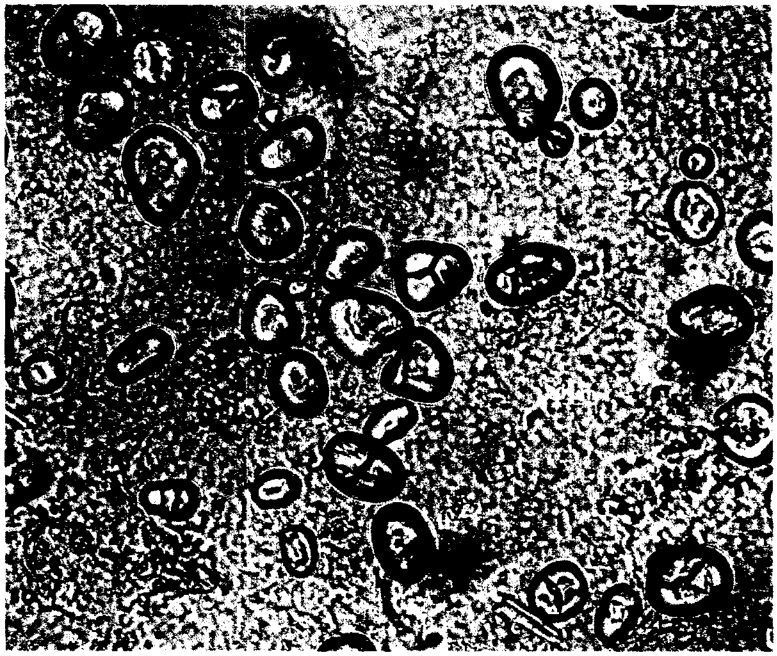

Figure 44.3: Damaged Starch from *Cajanus cajun*

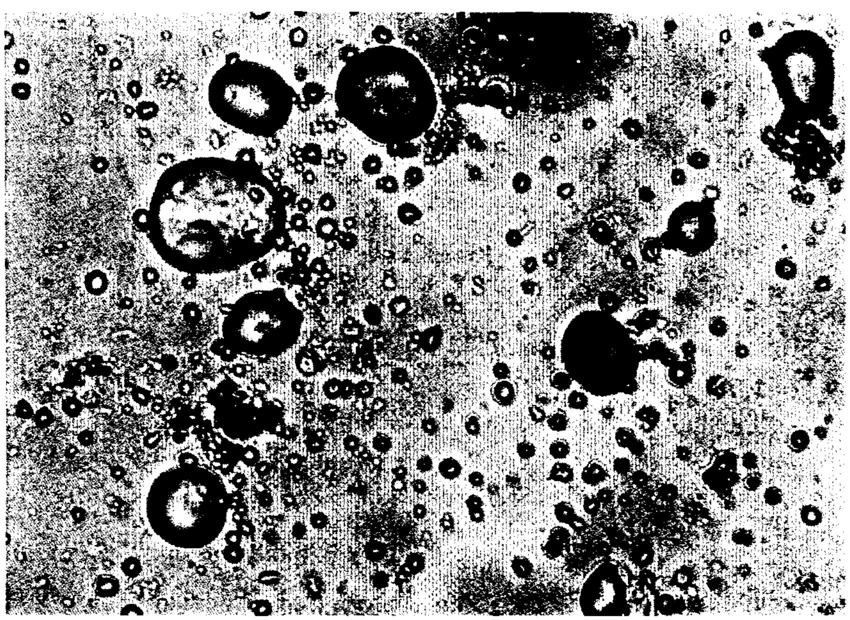

Figure 45.1: Oval and Circular Starches from *Hordeum vulgare*

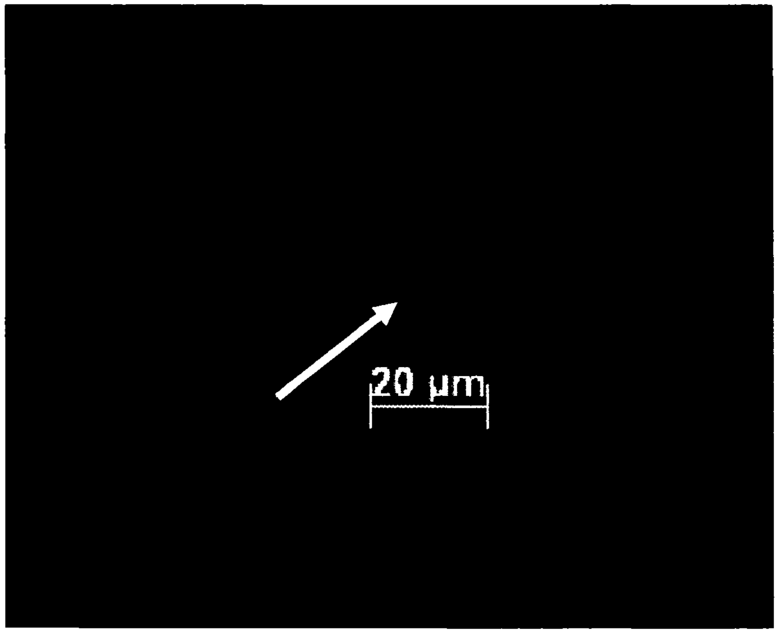

Figure 45.2: Crater like Appearance in *Hordeum vulagare* Starches

APPENDIX F (CONTD.)

Scientific Name	Size	Description
Sorghum bicolor L. or Millet Sorghum (Figure 46.1– 46.4)	Varies from – 8.68 – 30.52µm, some grains are as big as 60µm Average – 27.81µm	Grains are simple sphere in shape, when rotated they look like dices. Lamellae are present. Some of the grains when turned are round and have a band around the center. They also have double edges. There is a depression in the center and there are striations all around the center (looks like cut kiwi fruit). Hilum is centric and some have fissures (X in shape and sometimes stellate). Very distinct extinction cross under polarize light, the grains are dull and have a stony appearance.
Pennisetum glaucum or Pearl Millet (Figure 47.1–47.2)	Varies from – 7.66 – 15.2µm Average – 11.36µm	Very similar to Sorghum bicolor, only the grains are much smaller and fragile looking and the hilum has no fissures it is in form of a big point
Eleusine coracan L. or Finger Millet (Figure 48.1–48.3)	Not enough measurements were taken because the modern sample was milled	Compound grain with several starch granules, clustered together, could not separate at all (this is an important characteristic not seen in other starches studied) individual granules are hemispherical shape with pressure facets and they are raised in the center
Oryza sativa or Rice (Figure 49.1– 49.3)	Varies from – 3.72 – 9.97µm Average – 6.62µm	Rice starches have very small compound granules, they are polygonal (mostly five sided) and very sharp and angular and frequently aggregated into clusters. In three dimensions they look like crystals, they have a centric hilum. In most of the grains the extinction-cross cuts through the center of the grains.
Triticum aestivum or Wheat	Varies from – 8 – 30µm	Contains large, round, lens shaped granules and small spherical granules. There are no demonstrable lamellae. Some of the grains have dimples on them which give them a small crater like appearance.

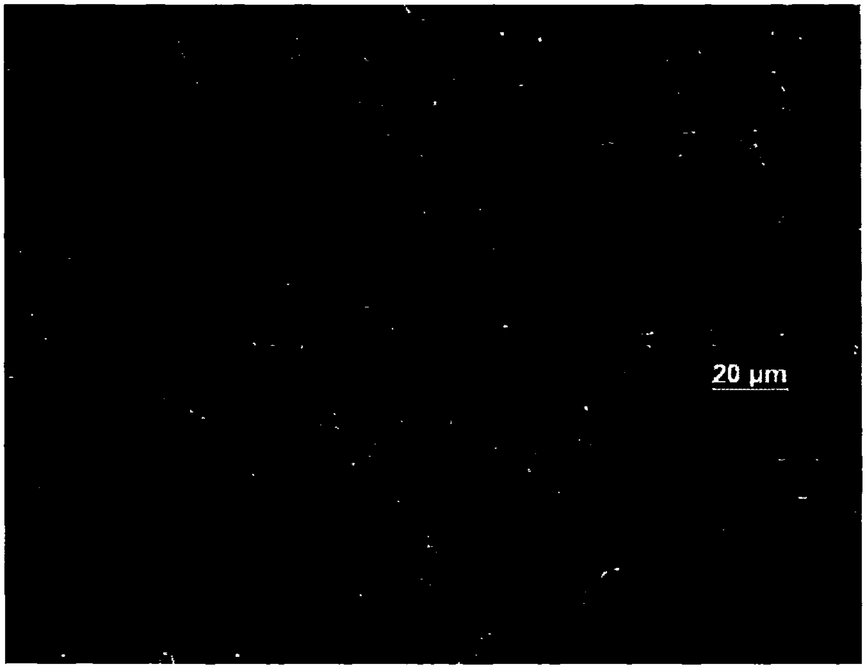

Figure 46.1: Starches from *Sorghum bicolor*

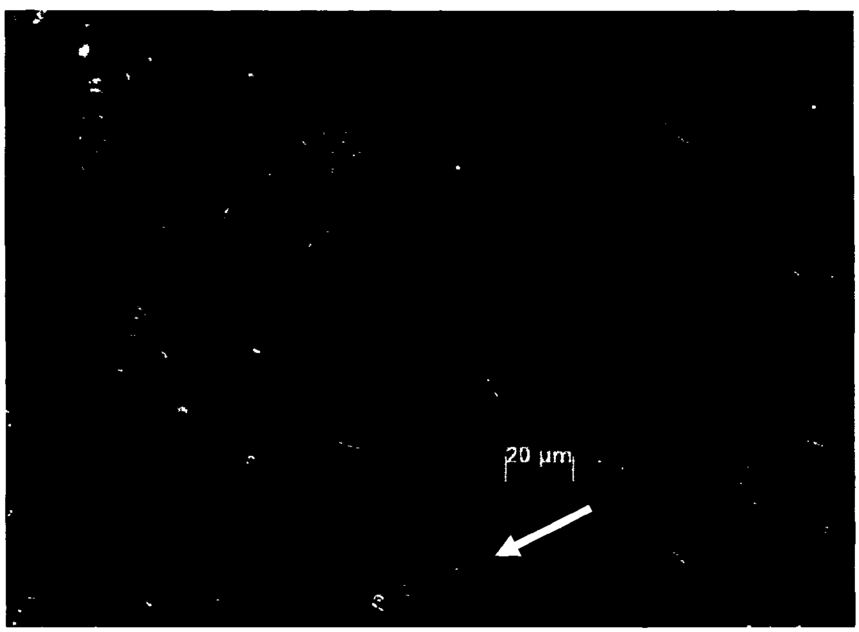

Figure 46.2: Prominent Extinction Cross and Centric Hilum *Sorghum bicolor*

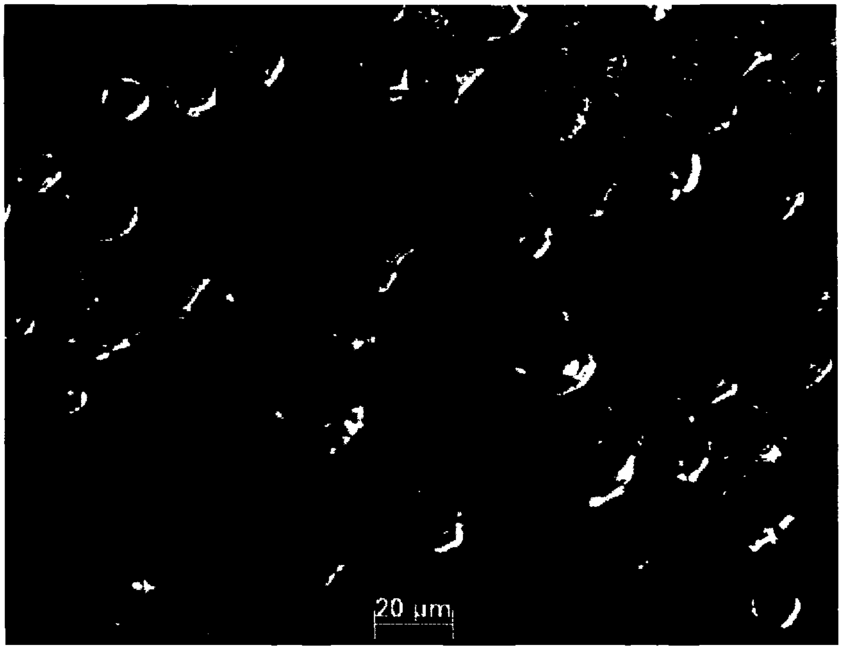

Figure 46.3: Starches from *Sorghum bicolor* (under polarize light)

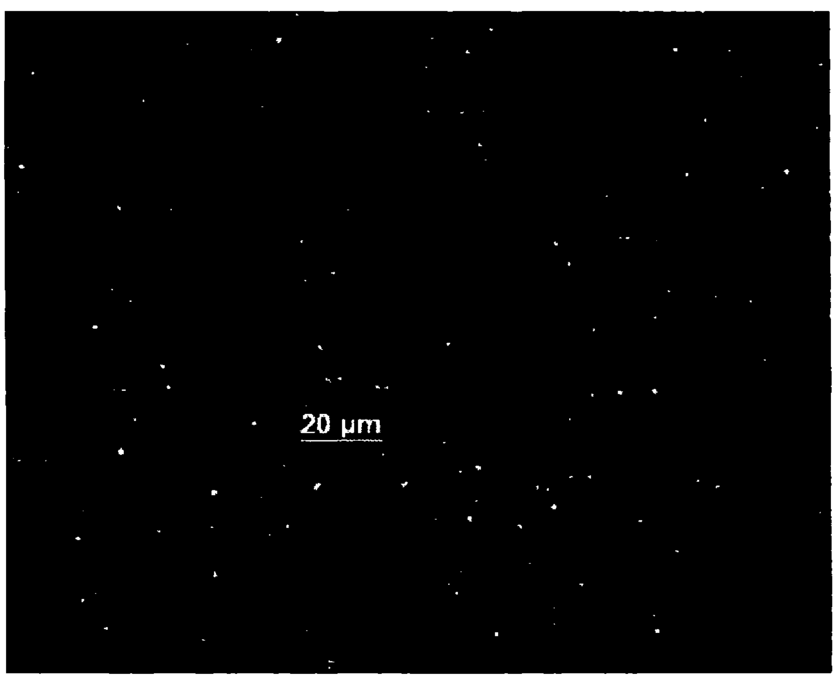

Figure 46.4: Spherical Starches with Pressure Facets from *Sorghum bicolor*

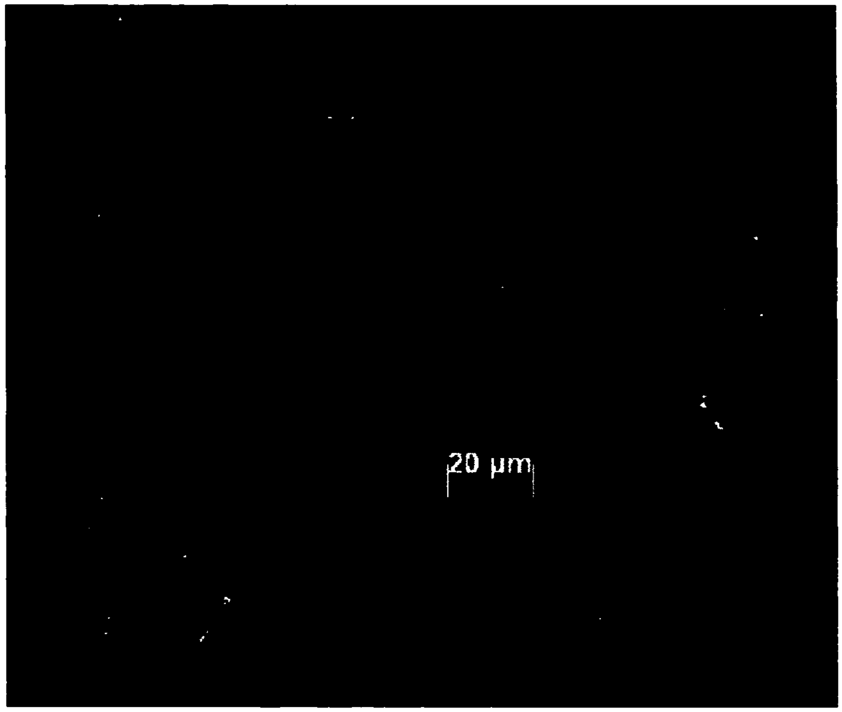

Figure 47.1: Starches with Pressure Facets from *Pennisetum glaucum*

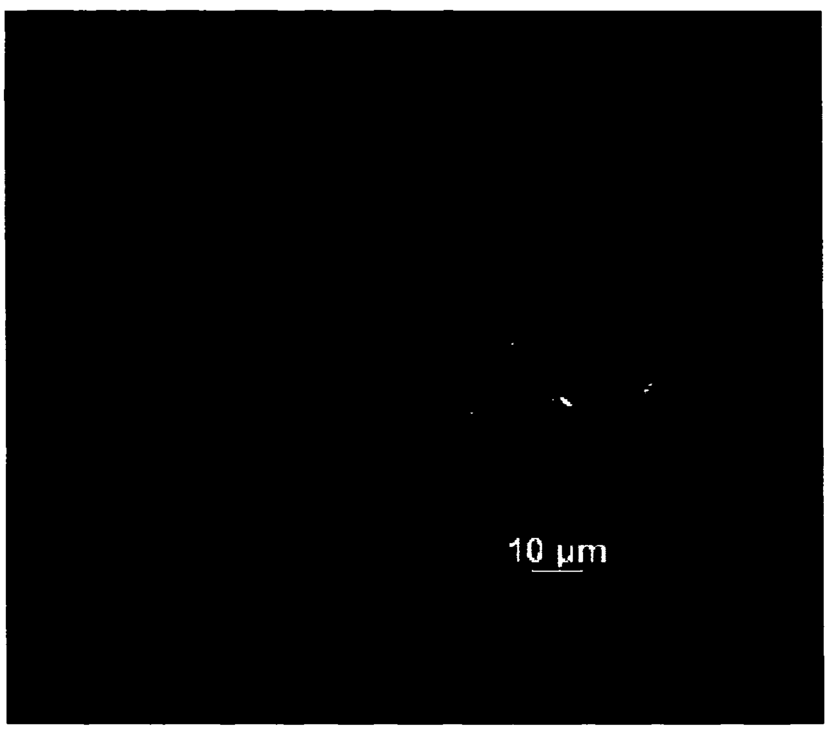

Figure 47.2: Starches from *Pennisetum glaucum* (under polarize light)

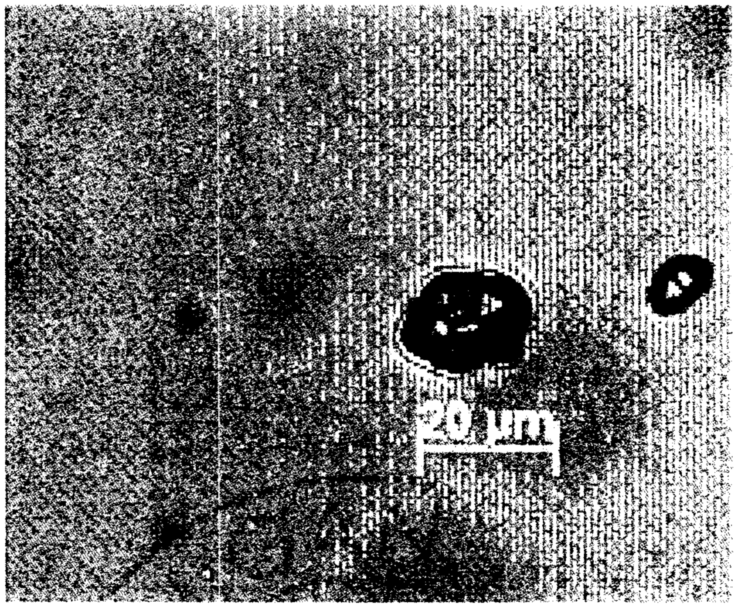

Figure 48.1: Compound Starches from *Eleusine coracan* L.

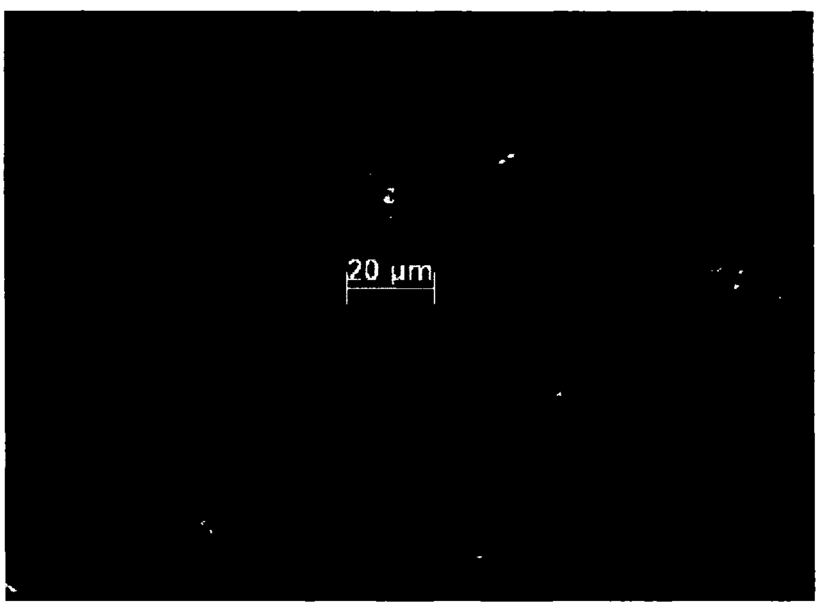

Figure 48.2: Compound Starches from *Eleusine coracan* L. (under polarize light)

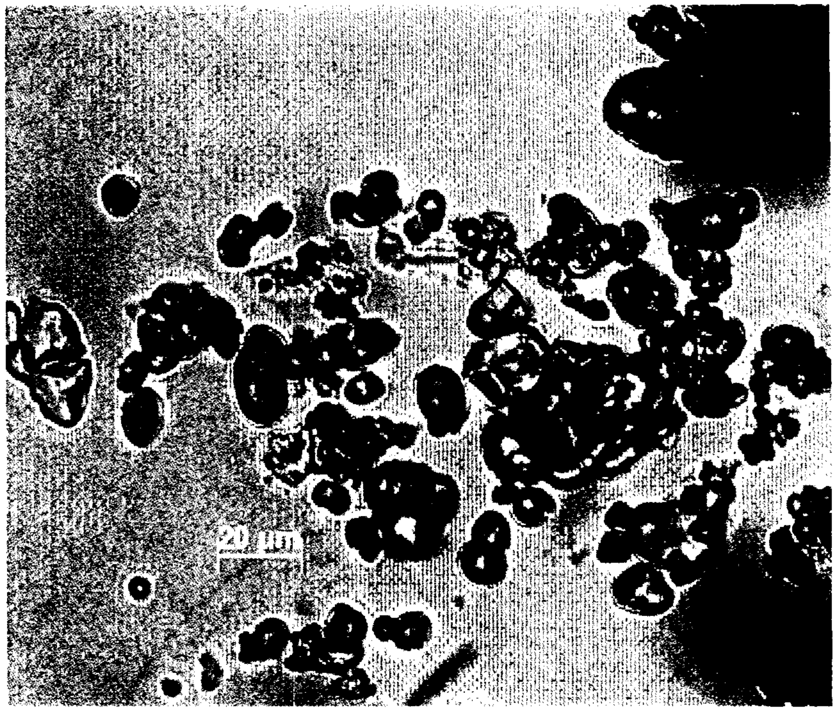

Figure 48.3: Starches from *Eleusine coracan* L.

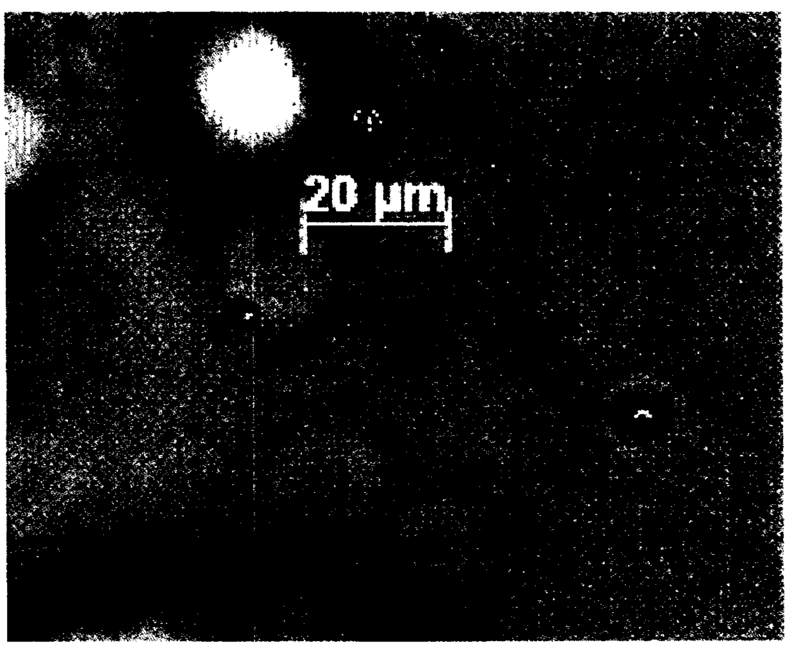

Figure 49.1: Compound Starches from *Oryza sativa*

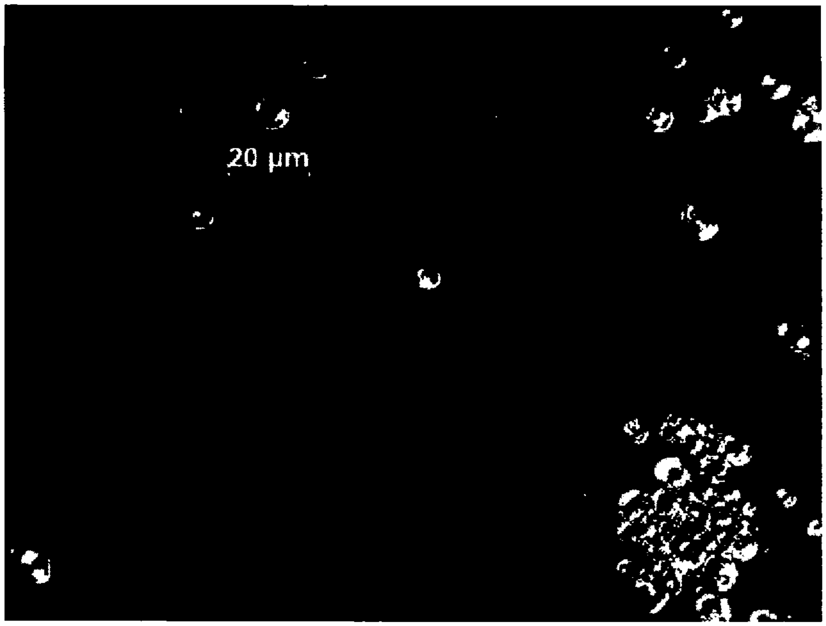

Figure 49.2: Compound Starches from *Oryza sativa* (under polarize light)

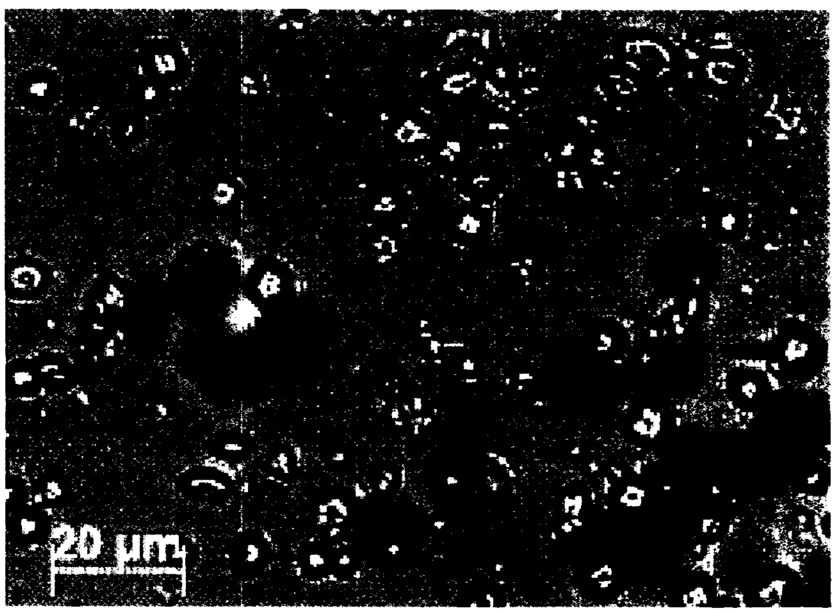

Figure 49.3: Extinction Cross and Characteristic Double Edges of Oryza

APPENDIX F (CONTD.)

Scientific Name	Size	Description
Ipomoea batatas or Sweet Potato (Figure 50.1–50.4)	Varies from – 7.8 – 37.85μm Average – 20.47μm	Starch grains are bell shaped, mostly compound grains, laminated, hilum is centric. They have prominent small fissures. In three dimensions the grains look hemispherical.
Zingiber officinale Rosc. Or Ginger (Figure 51.1–51.2)	Length Varies from = 13.12 – 39.89μm Width Varies from = 11.43 – 26.11μm Average Length – 26.95μm Average Width – 20.20μm	Starches are elongate shape with a projection at one end and one end is more rounded. Hilum when seen is eccentric and is open. Lamellae are faint and look like oyster shell. In three dimensions the starches look like lens and are very narrow. Pressure facets are seen and there is a crease on some of the starches. There are two distinct edges on the starch, extinction cross is visible under polarize light.
Kaempferia galang or Galanga (Figure 52.1–52.2)	Length Varies from = 14.33 – 26.45 μm Average Length – 22.25μm Width Varies from = 7.37 -16.45μm Average Width – 11.71μm	Galanga belongs to the same family as ginger and turmeric. Starch grains are very narrow and elongate. The average size of both the width and the length are much smaller than ginger. Extinction cross is very prominent. Lamellae is very pronounced even more than turmeric
Curcuma longa or Turmeric (Figure 53.1–53.3)	Length Varies from = 18.31 – 50.67μm Average Length – 32.37μm Width varies from = 14.04 – 32.07μm Average Width – 20.38μm	Turmeric starches are much larger but narrower than the ginger starches. They are elongate, the grain on the one side is rounded and other side has a projection, the projection unlike ginger is not pointed but curved, on some of the grains the rounded edge has a little pointed side too. Lamellae are thicker than the ginger and looks like an oyster shell.
Tamarindus indica L. or Tamarind (Figure 54.1–54.4)	Length Varies from = 2.15 – 26. 67 μm Average Length – 7.7μm	Spherical (from fruit) and Elongate (from seed). Both elongate and hemispherical have fissures. Spherical have centric hilum and have several pressure facets on rotation they look like oval vases with facets.

Figure 50.1: Bell Shaped Starch Grains from *Ipomoea batatas*

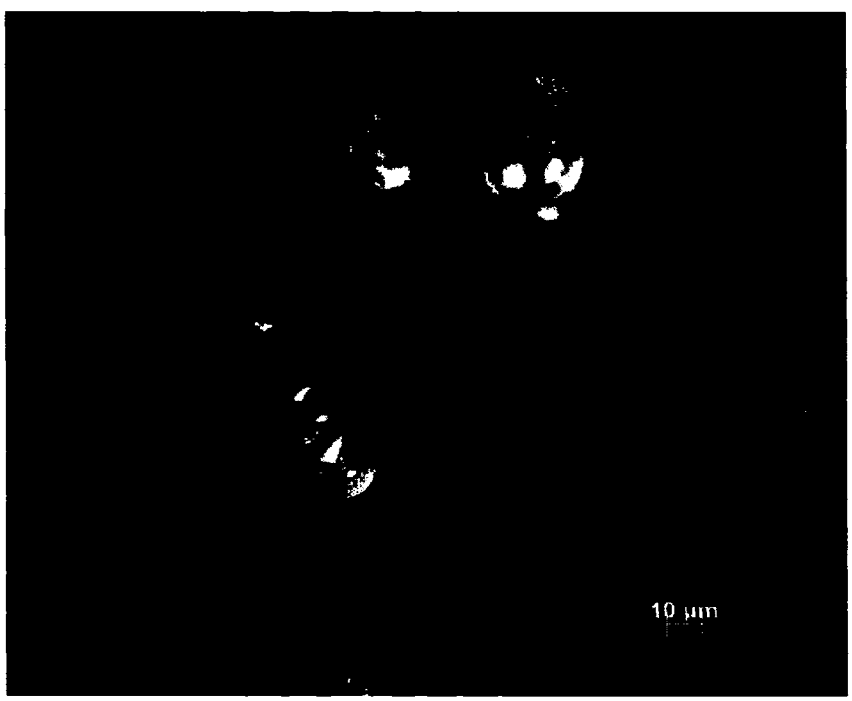

Figure 50.2: Bell Shaped Starch Grains from *Ipomoea batatas* (under polarize light)

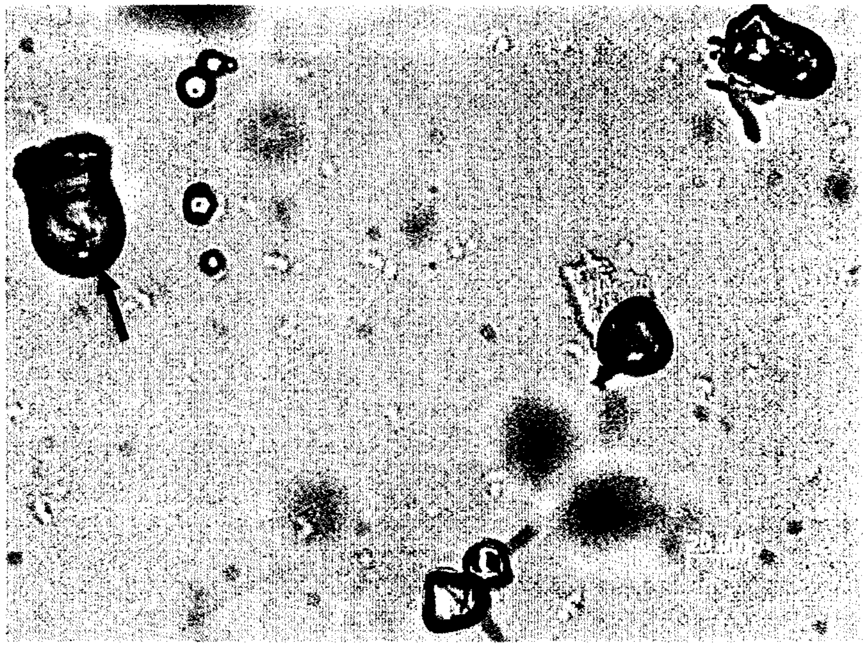

Figure 50.3: Bell Shaped Grains with Characteristic Extinction Cross from *Ipomoea batatas*

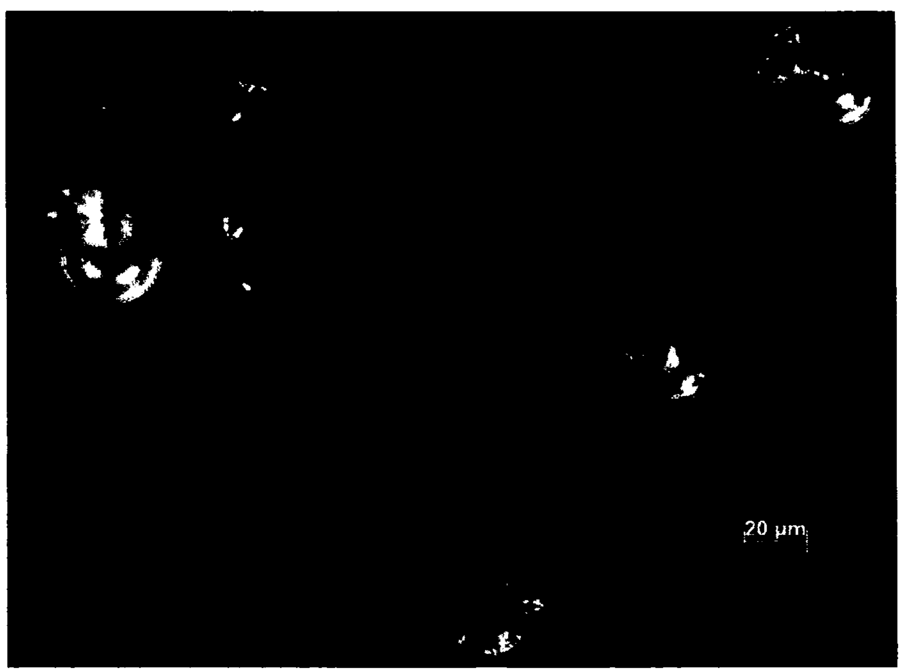

Figure 50.4: Bell Shaped Grains with Characteristic Extinction Cross from *Ipomoea batatas* (under polarize light)

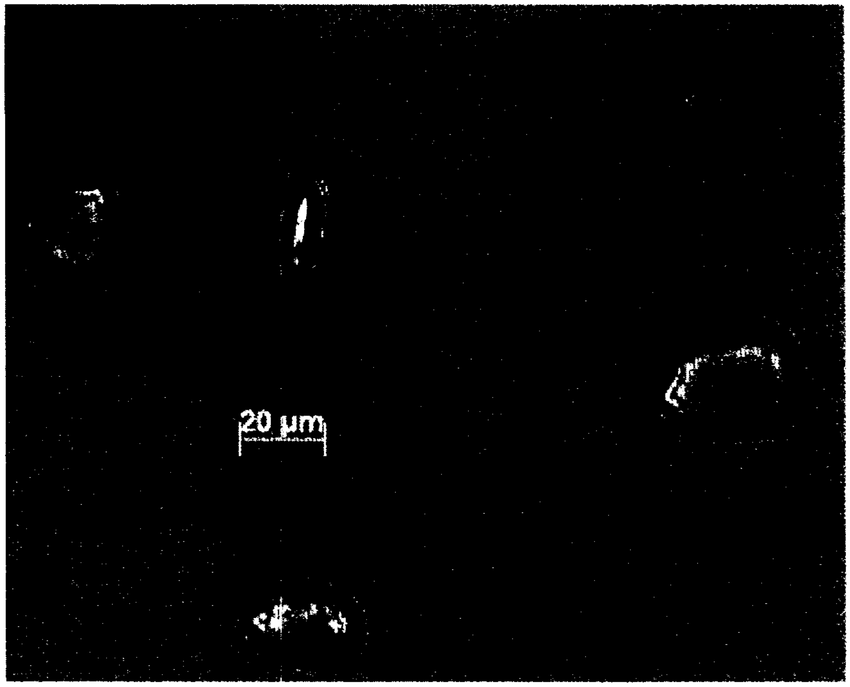

Figure 51.1: Starches from *Zingiber officinale Rosc*

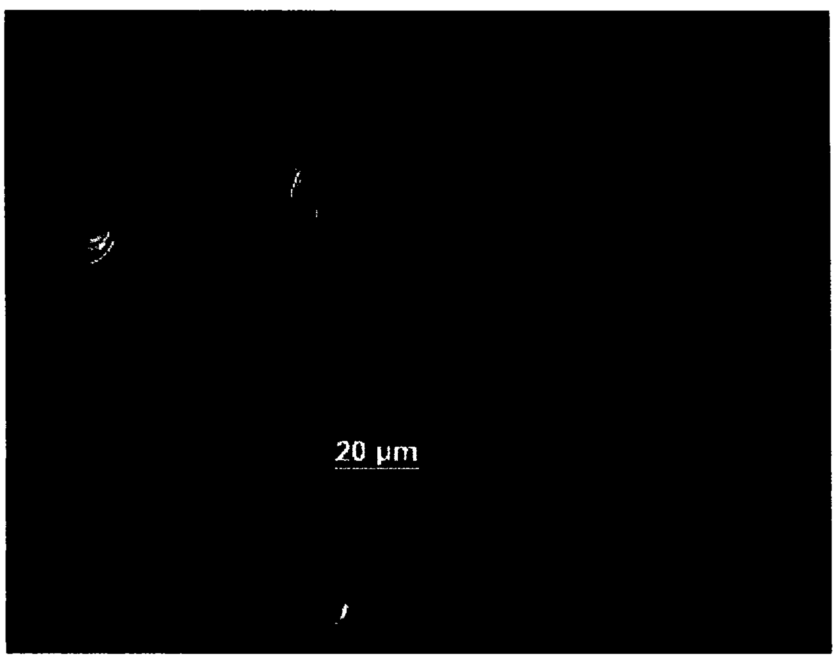

Figure 51.1: Starches from *Zingiber officinale Rosc* (under polarize light)

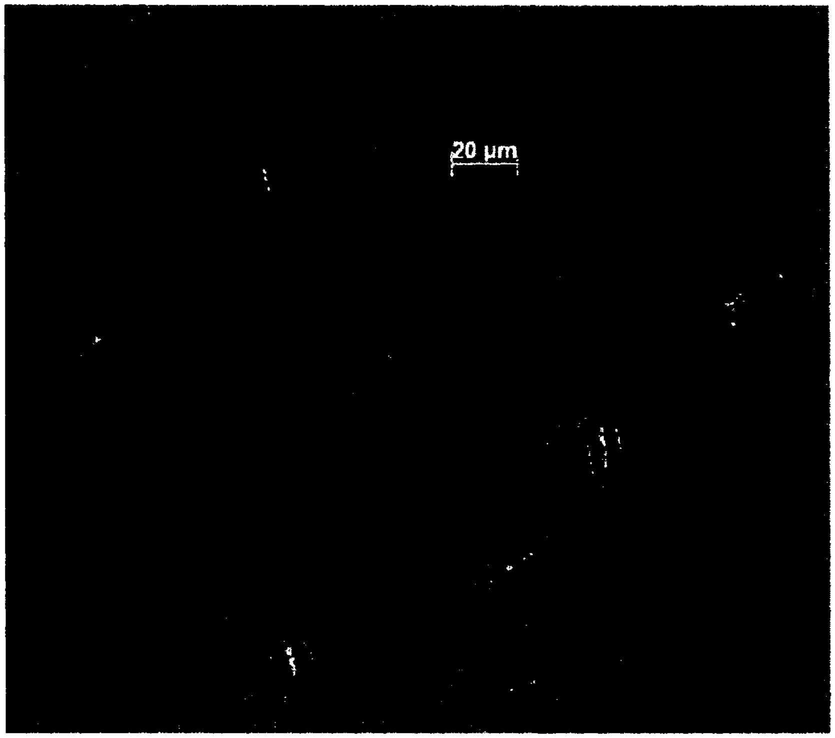

Figure 52.1: Starches from *Kaempferia galang*

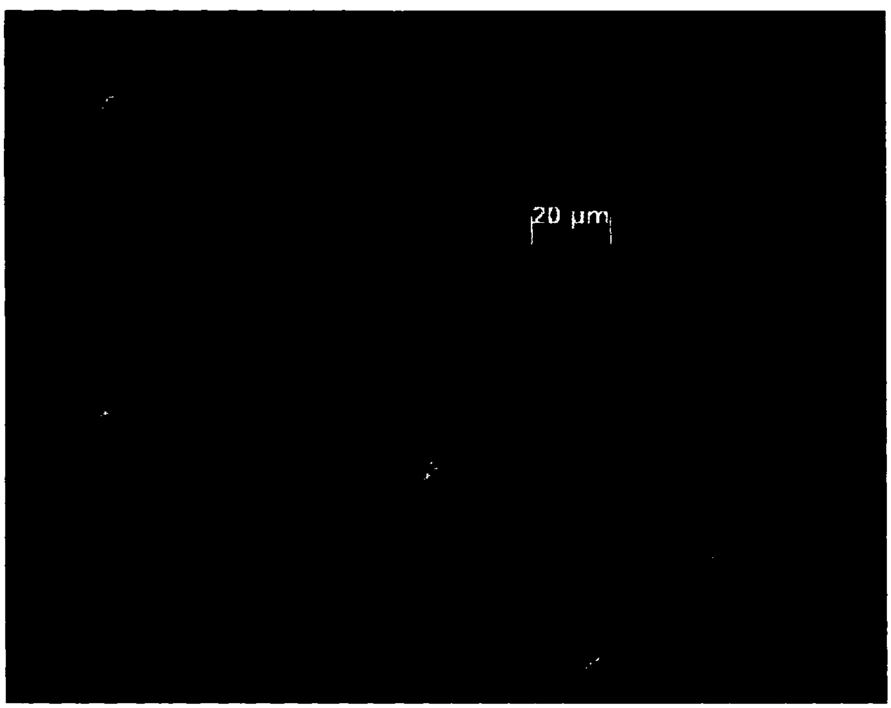

Figure 52.2: Starches from *Kaempferia galang* (under polarize light)

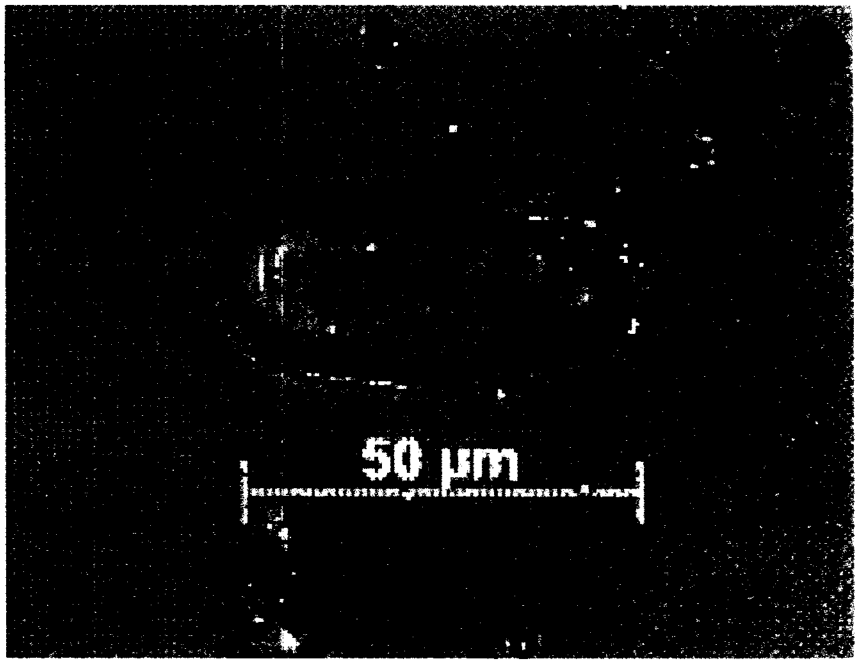

Figure 53.1: Starches from *Curcuma longa*

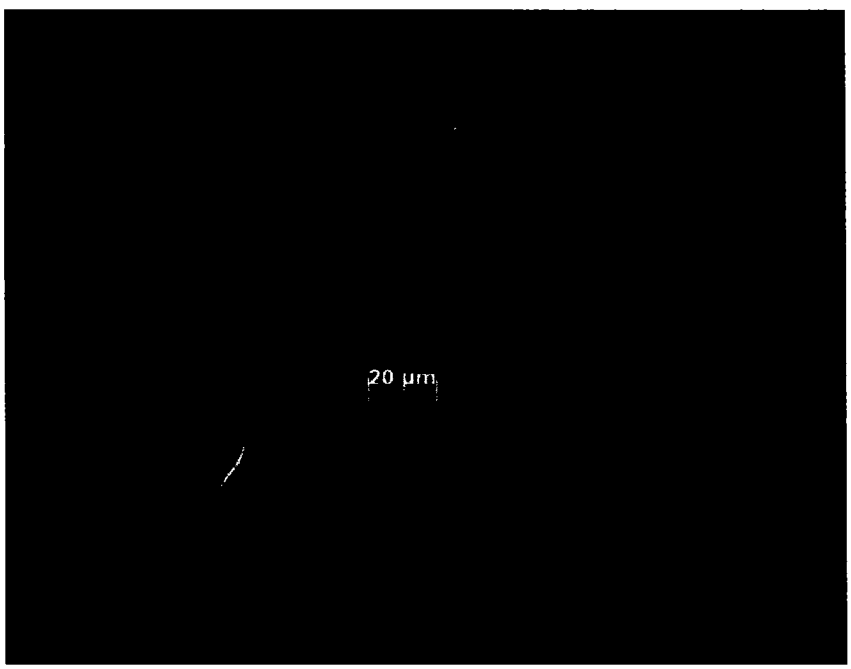

Figure 53.2: Starches from *Curcuma longa* (under polarize light)

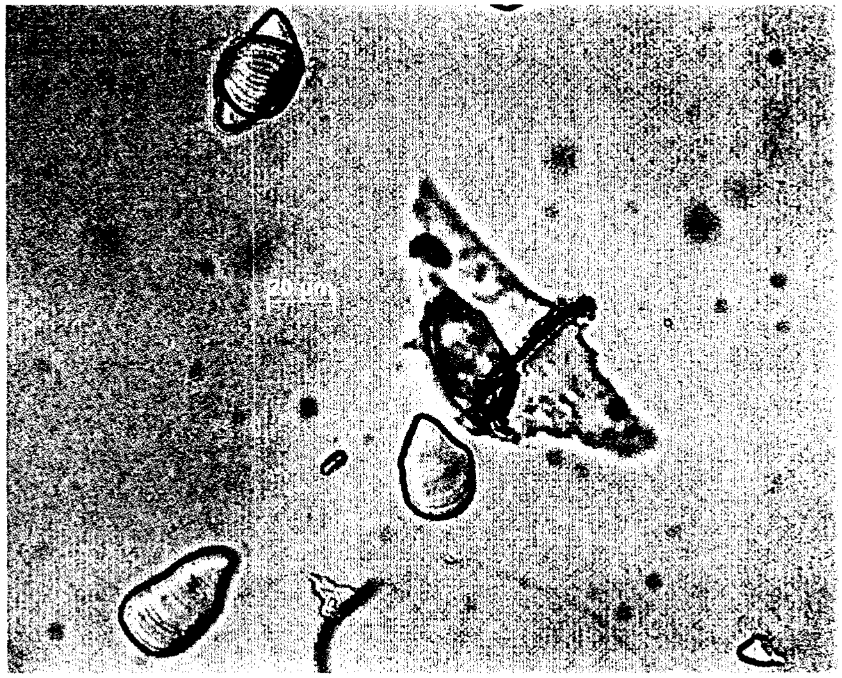

Figure 53.3: Oyster Shell like Lamellae in *Curcuma longa*

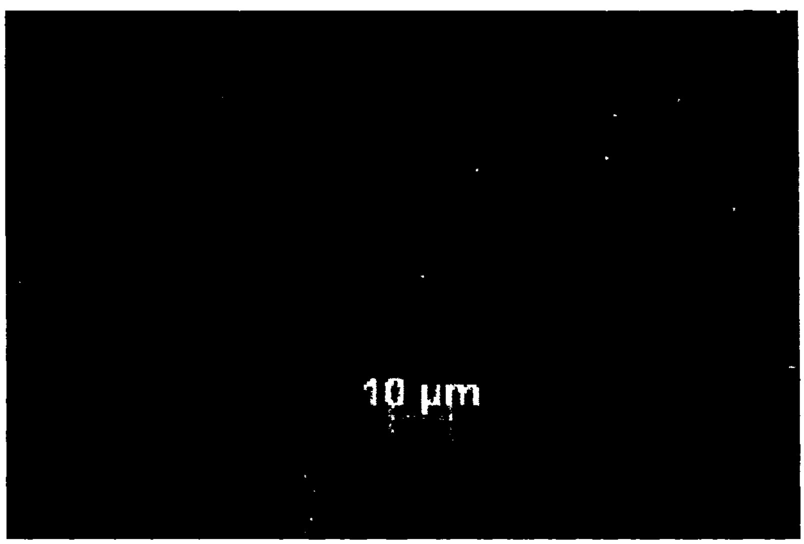

Figure 54.1: Spherical Starches Pericarp of *Tamarindus indica L.*

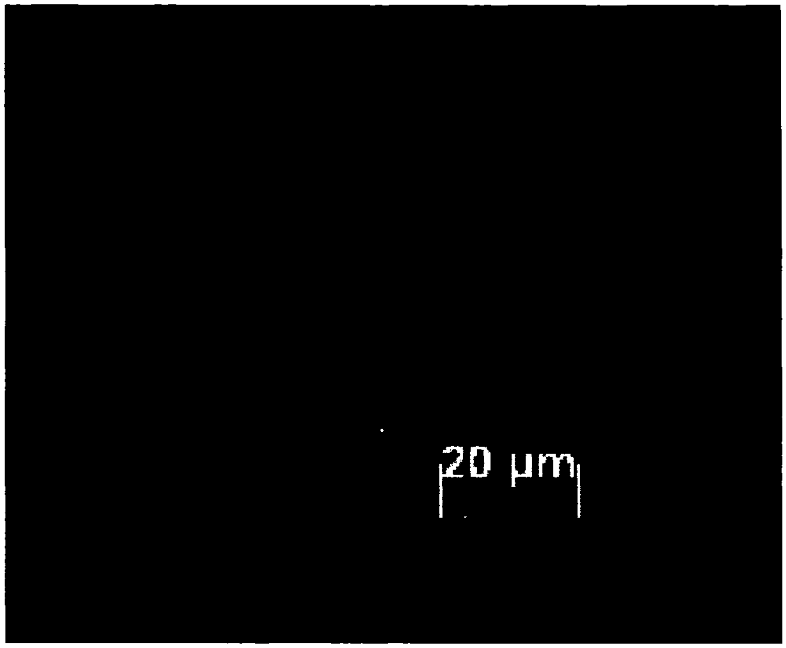

Figure 54.2: Spherical Starches from *Tamarindus indica L.* (under polarize light)

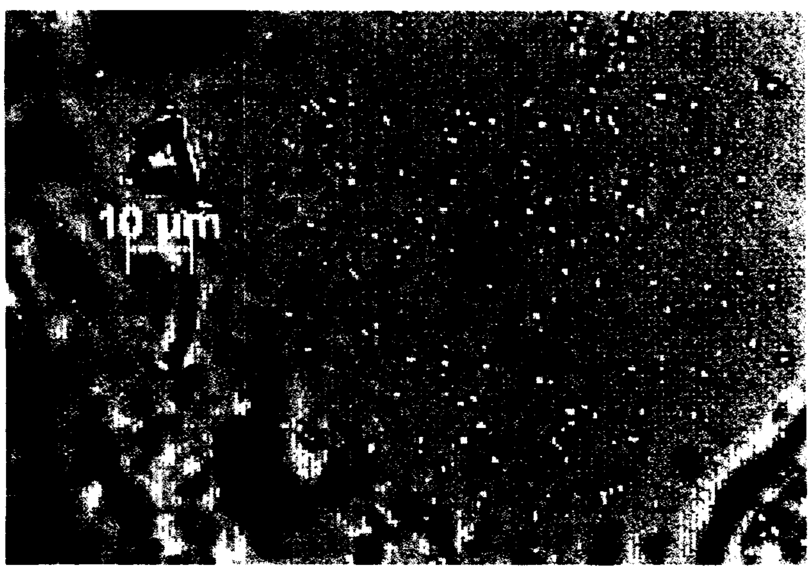

Figure 54.3: Spherical Starches from Pericarp of *Tamarindus indica L.* on rotation

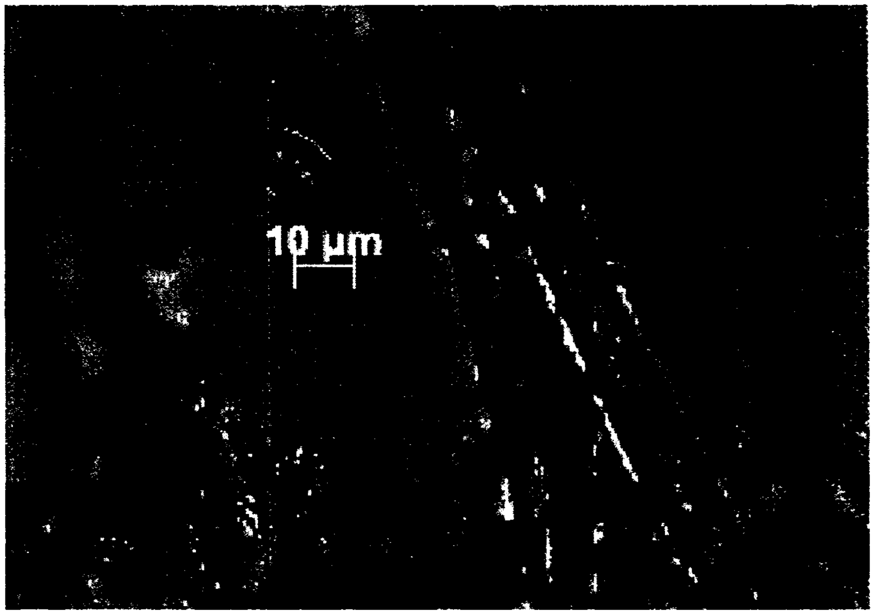

Figure 54 D: Elongate Starches from Seed of *Tamarindus indica L.*

APPENDIX F (CONTD.)

Scientific Name	Size	Description
Amorphophallus campanulatus or Yam (Figure 55.1–55.2)	Varies from – 5.39 – 26.89µm Average – 13.95µm	Compound grains, hemispherical in shape with basal facets which are very distinct. The starches rotate to become bell shaped, hilum when seen is eccentric
Colocassia esculenta or Taro (Figure 56.1– 56.2)	Varies from – 1.91 - 5.45µm Average – 2.90µm	Starches are compound and very, very tiny. They are hemispherical in shape. Hilum is in the center.
Mangifera or Mango (Figure 57.1 –57.2)	Varies from – 6.26 – 24.25µm Average – 14.44µm	Starch grains are spherical, on rotation looks more elongate, on one side it looks very flat and on the other side it looks like raised like a cake with a hole in it, hilum is centric, around the hilum are small dots which under polarize light look like stars in a clear sky, there is light radiating from between the two lines on the edge
Solanum or Egg Plant (Figure 58.1–58.3 and Figure 59.1–59.3)	Average Length - 19.79µm	The pericarp and seeds of Eggplant produces different kinds of starches. The starches from the pericarp are oval to elongate in shape, wide, there are thick bands, hilum is eccentric, there are several pits in the starch, the starch has two distinct edges, under polarize light there are bands, which look like orbits around planets, there is a depression in the center, there is a dark band at the edge. The seeds of egg plant produces distinct bell shaped/hemispherical on rotation starches. Hilum is centric and they have a characteristic y or x shaped fissures in the center.
Nymphaea lotus L. or Lotus (Figure 60.1–60.2)	Varies from 3 – 7.9µm	Starches from the root of the lotus were studied. A grinder was used to pound the root. The residue from the grinder was removed and studied. Very few grains only 12 could be retrieved from the grinder. The starch grains look like rose petals, hilum is centric.

Figure 55.1: Hemispherical starches from *Amorphophallus campanulatus*

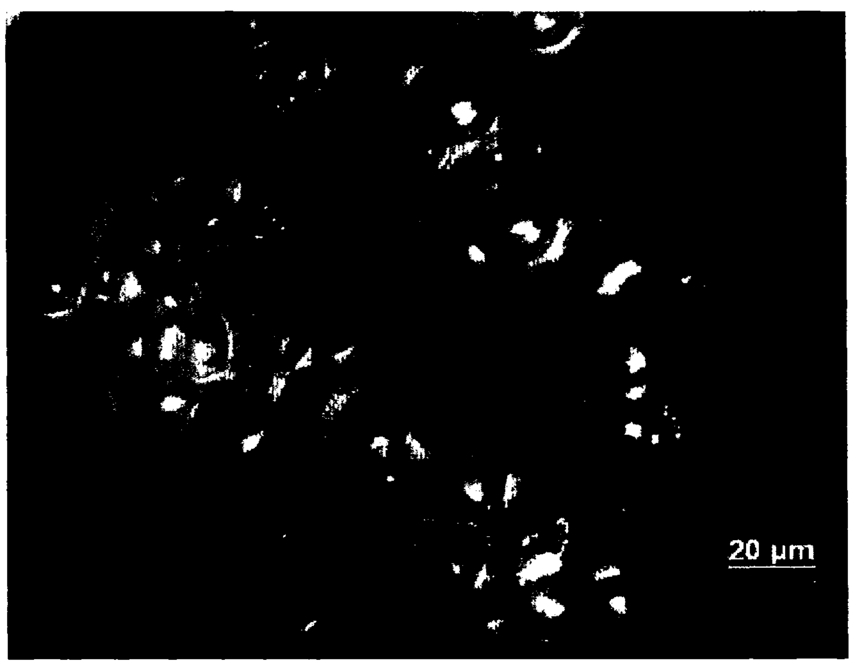

Figure 55.2: Hemispherical starches from *Amorphophallus campanulatus* (under polarize light)

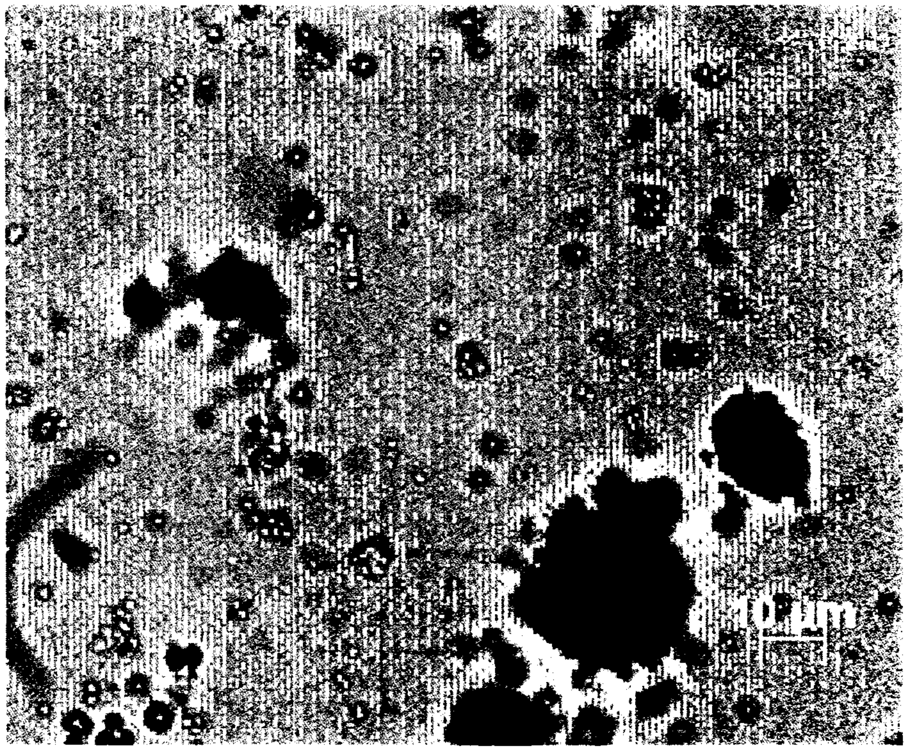

Figure 56.1: Starches from *Colocassia esculenta*

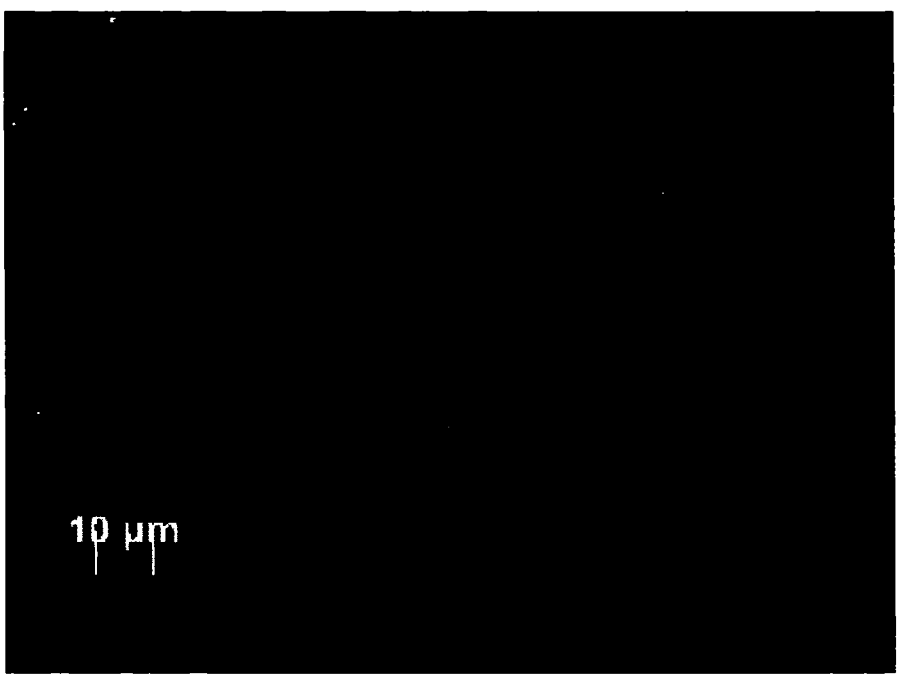

Figure 56.2: Starches from *Colocassia esculenta* (under polarize light)

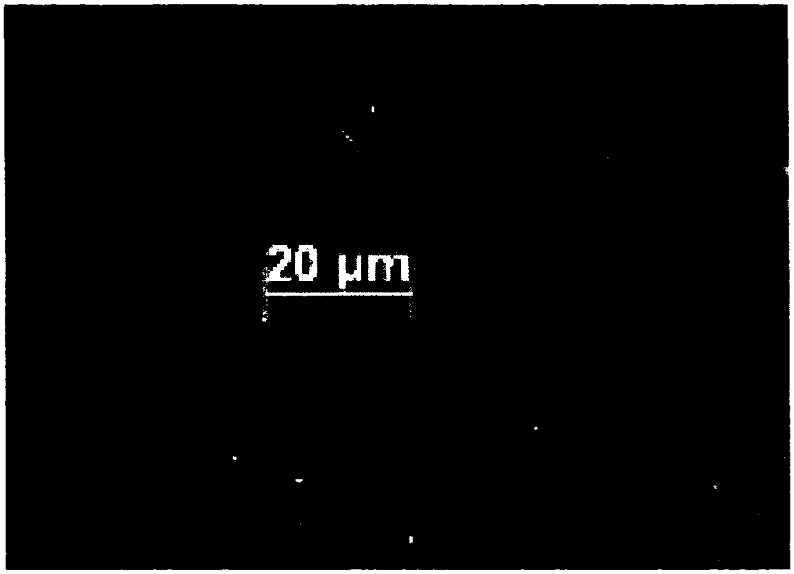

Figure 57.1: Spherical Starches from *Mangifera*

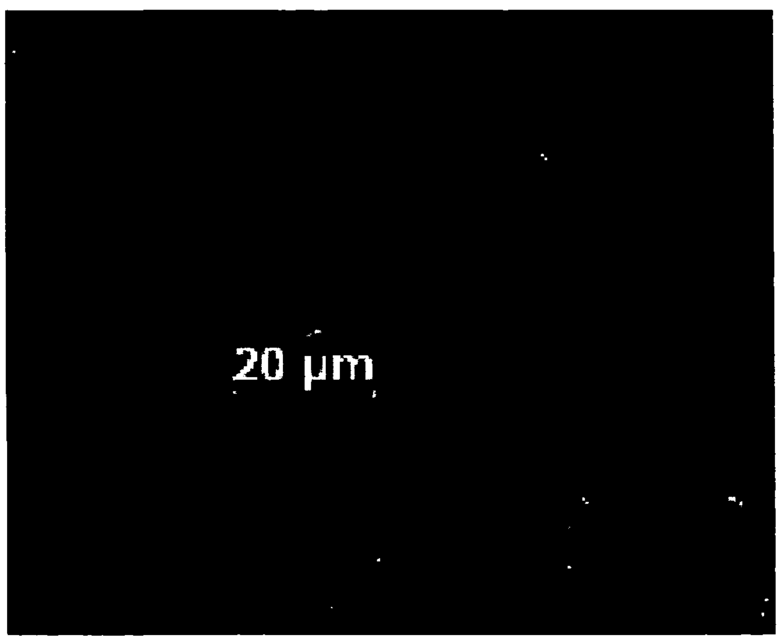

Figure 57.2: Spherical Starches from *Mangifera* (under polarize light)

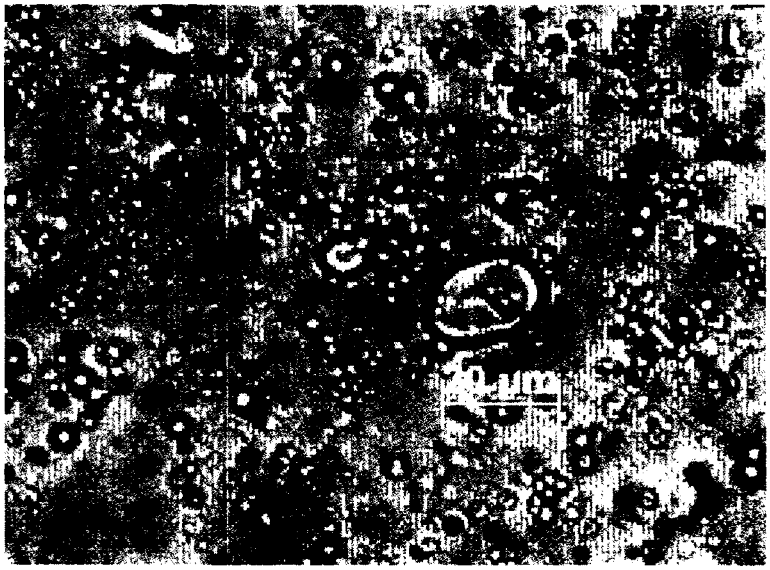

Figure 58.1: Elongate Starch from Pericarp of *Solanum*

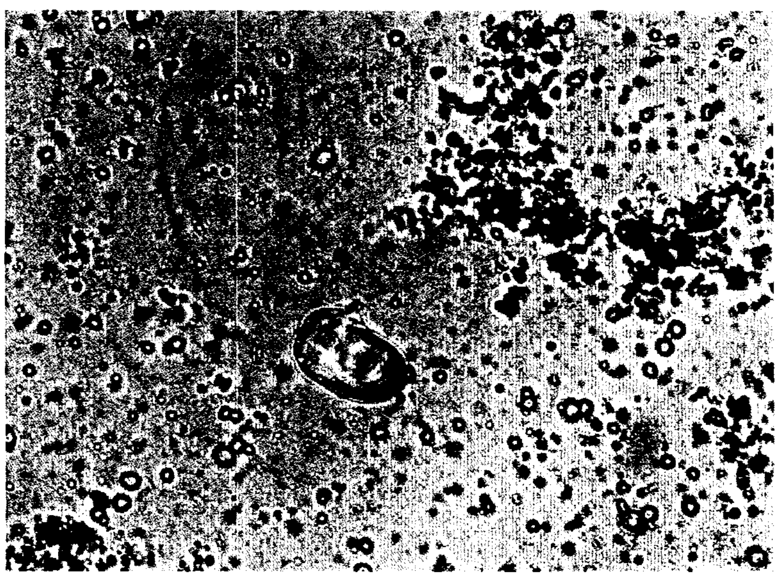

Figure 58.2: Elongate Starch from Pericarp of *Solanum* (characteristic double edges)

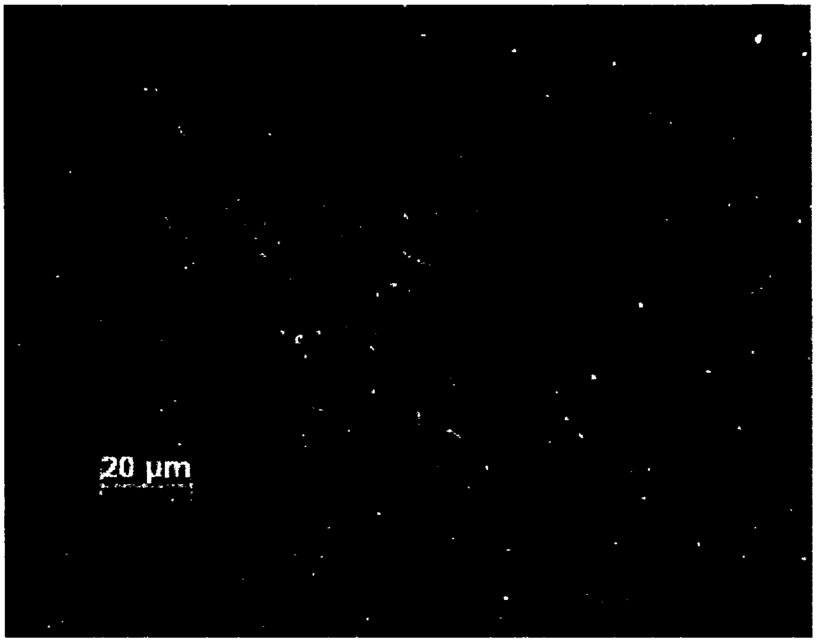

Figure 58.3: Elongate Starch from Pericarp of *Solanum* (see characteristic pits)

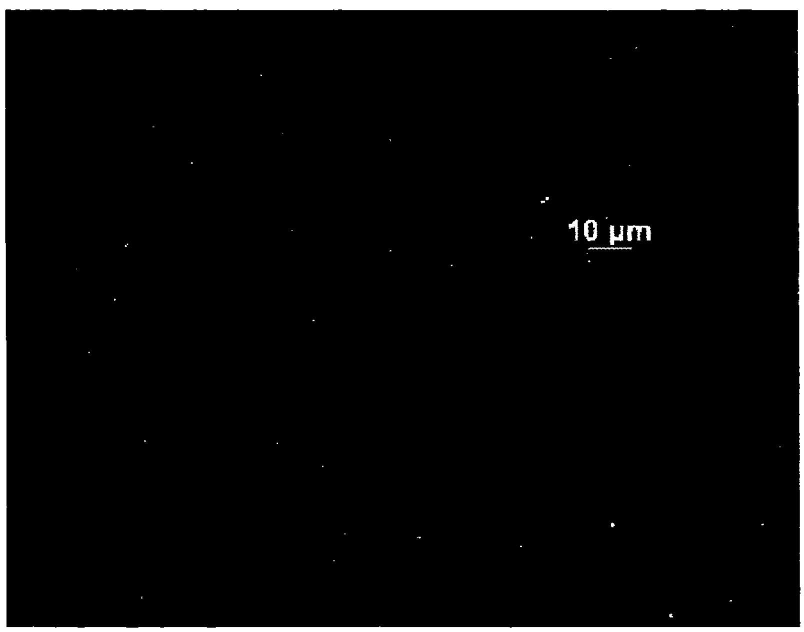

Figure 59.1: Bell Shaped Starch from Seed of *Solanum*

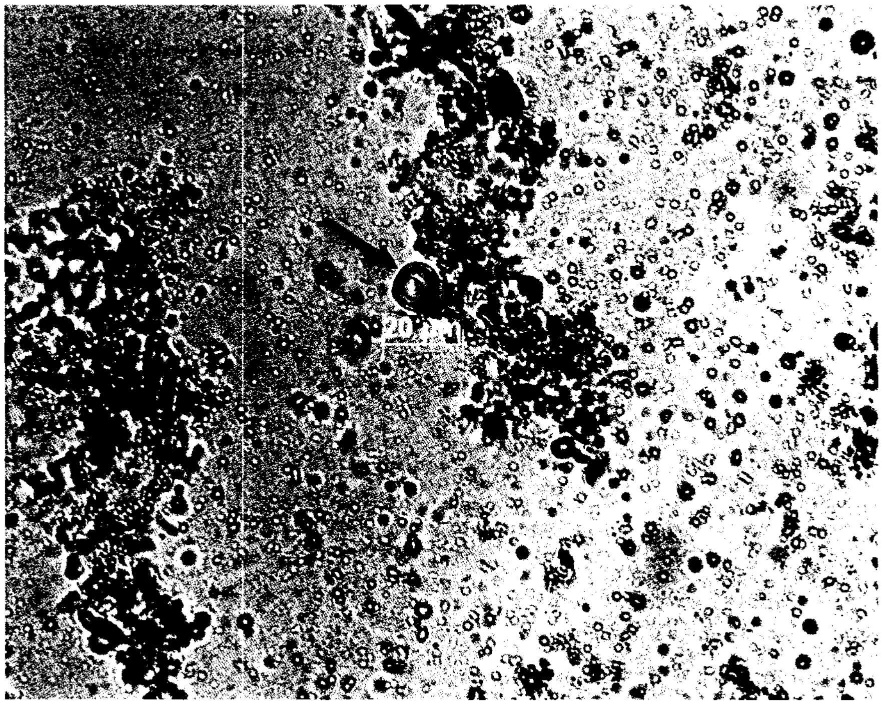

Figure 59.2: Characteristic X Shaped Fissure on Bell Shaped Starch from Seed of *Solanum*

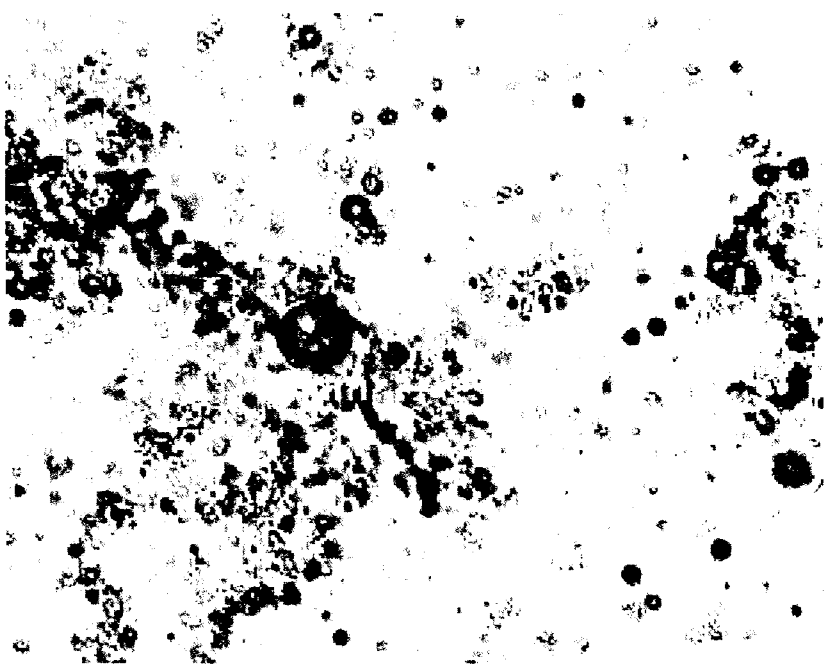

Figure 59.3: Bell Shaped Starch with X Shaped Fissure from Seed of *Solanum*

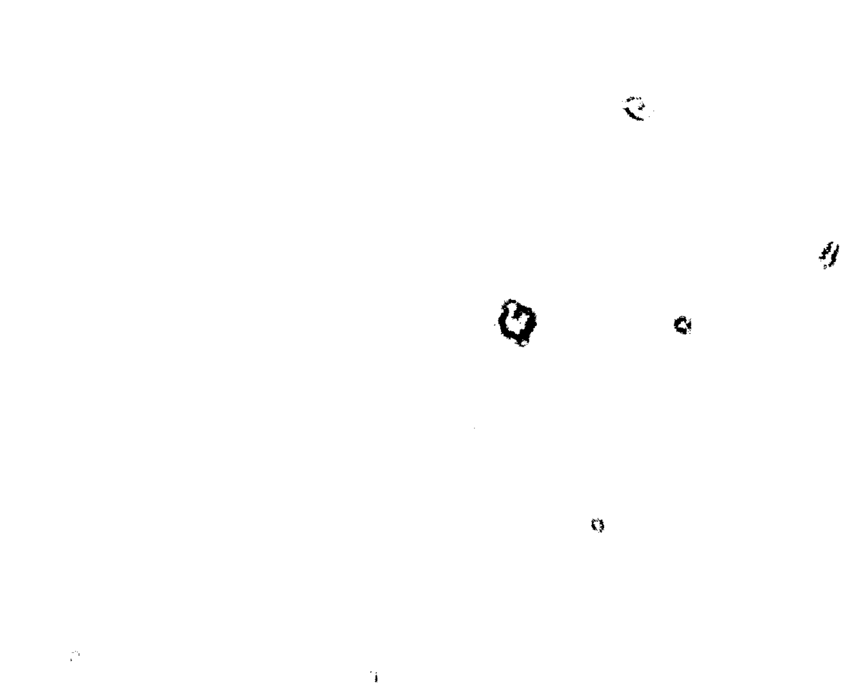

Figure 60.1: Starch from *Nymphaea lotus L.*

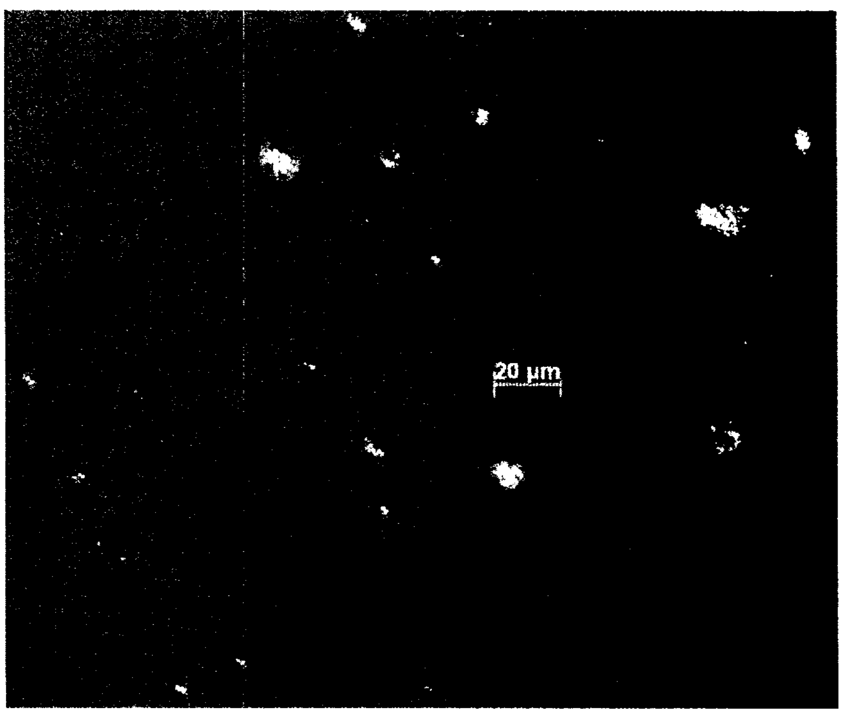

Figure 60.2: Starch from *Nymphaea lotus L.* (under polarize light)

APPENDIX G

SAMPLES STUDIED FROM ACERAMIC MESOLITHIC FOR STARCH GRAIN ANALYSIS

This appendix provides the context of the Samples studied for Starch grain Analysis for the Aceramic Mesolithic phase. It also provides the photographs of the starches found in each of the samples studied. (All pictures are 20 μm unless mentioned otherwise)

Sample Number	Residue Studied	Trench Number	Lot Number	Depth	Locus
Sample 1 (Retouched Blade) **(Figure 61. 1 – 61.5, 62.1-62.6)**	Tool Wash + Tool Sonic	1A	1007	- 50cm	All
Sample 6 (Unretouched Blade) **(Figure 63.1 – 63.15)**	Tool Wash + Tool Sonic	1C	3008	-54cm	South Half
Sample 7 (Unretouched Flake) **(No Starches)**	Tool Sonic	1C	3018	-74cm	South Half
Sample 9 (Retouched Blade) **(Figure 64.1 - 64.3)**	Tool Sonic	1A	1009	-72cm	All
Sample 10 (Crescent) **(Figure 65.1 – 65.5, 66.1 – 66.6)**	Tool Brush Tool Wash + Tool Sonic	1A	1011	-106cm	All
Sample 11 (Unretouched Blade) **(Figure 67.1 – 67.4)**	Tool Wash + Tool Sonic	1C	3008	-54cm	North Half
Sample 13 (Unretouched Blade) **(Figure 68.1 – 68.5)**	Tool Wash + Tool Sonic	1C	3017	-64cm	All
Sample 16 **(Figure 69.1 – 69.28)**	Grinder	1A	1012	-106cm	All
Sample 20 **(Figure 70.1-70.16)**	Soil	1A	1009	- 72 cm	All

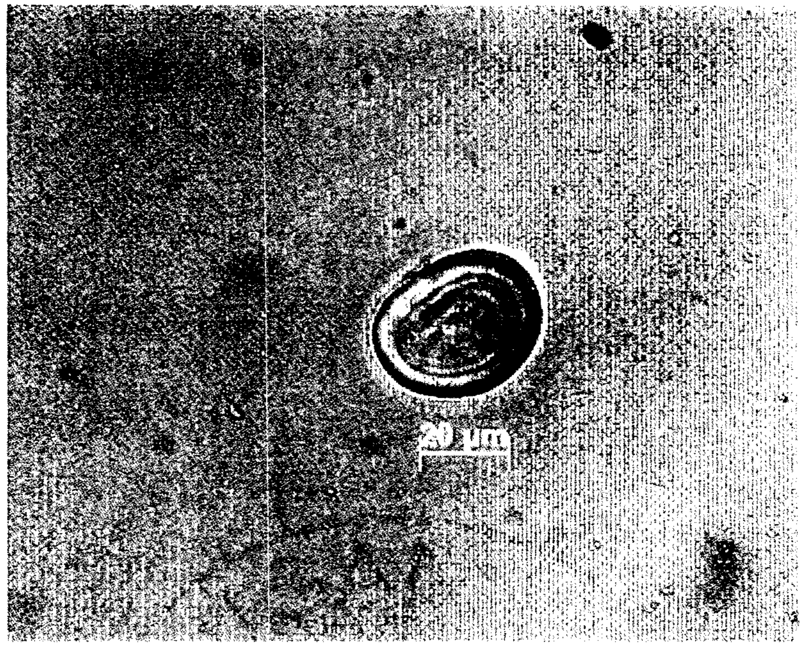

Figure 61.1: Starch grain from Pericarp of cf. *Solanum*

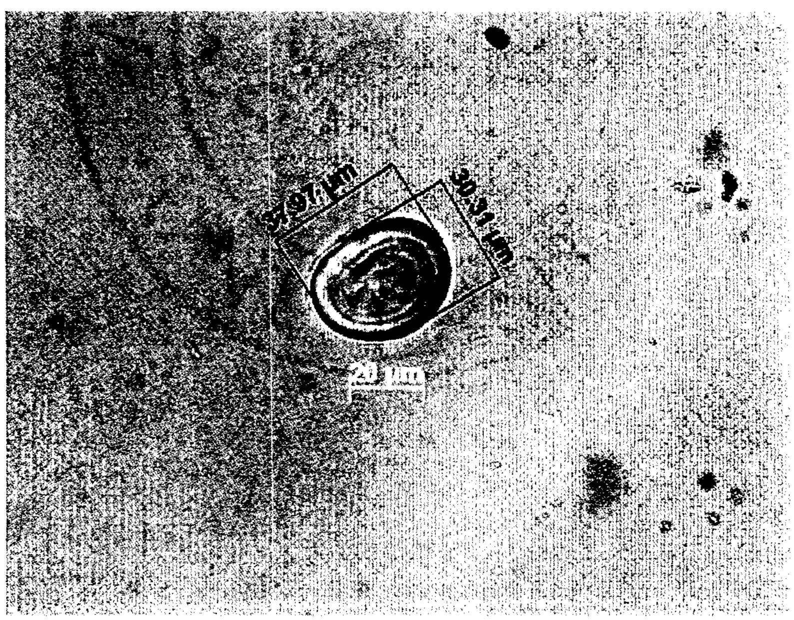

Figure 61.2: Starch grain from Pericarp of cf. *Solanum* (measurements)

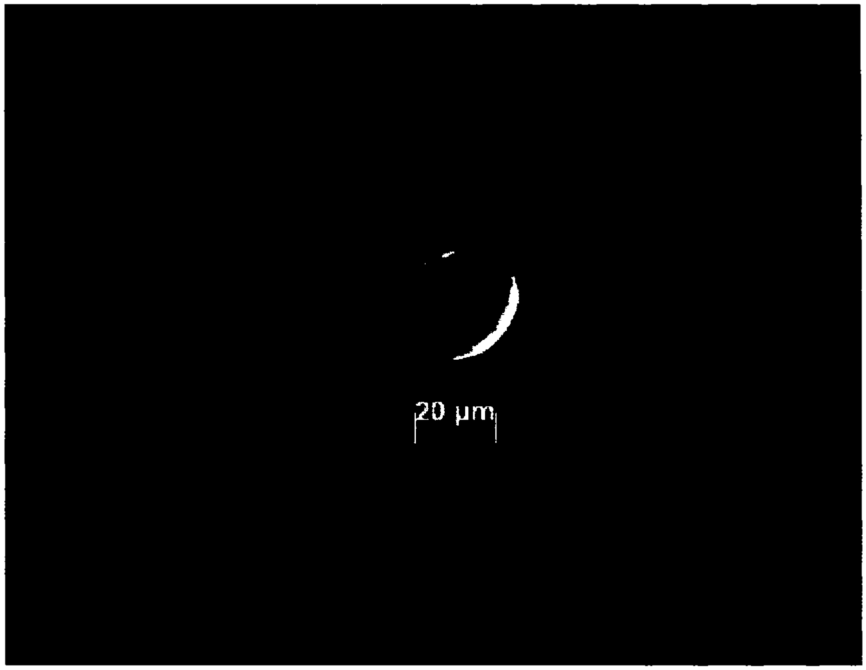

Figure 61.3: Starch grain from Pericarp of cf. *Solanum* (under polarize light)

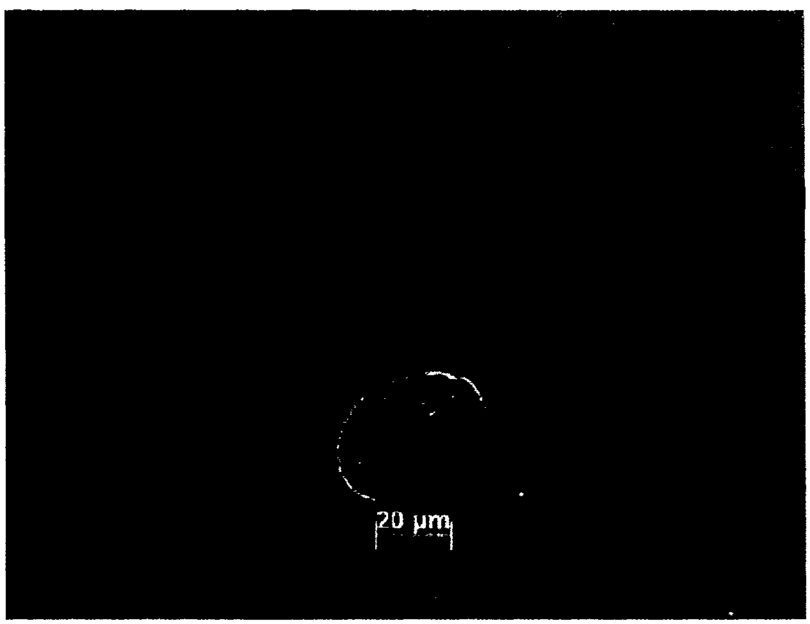

Figure 61.4: Damaged Starch Grain from pericarp of cf. *Solanum*

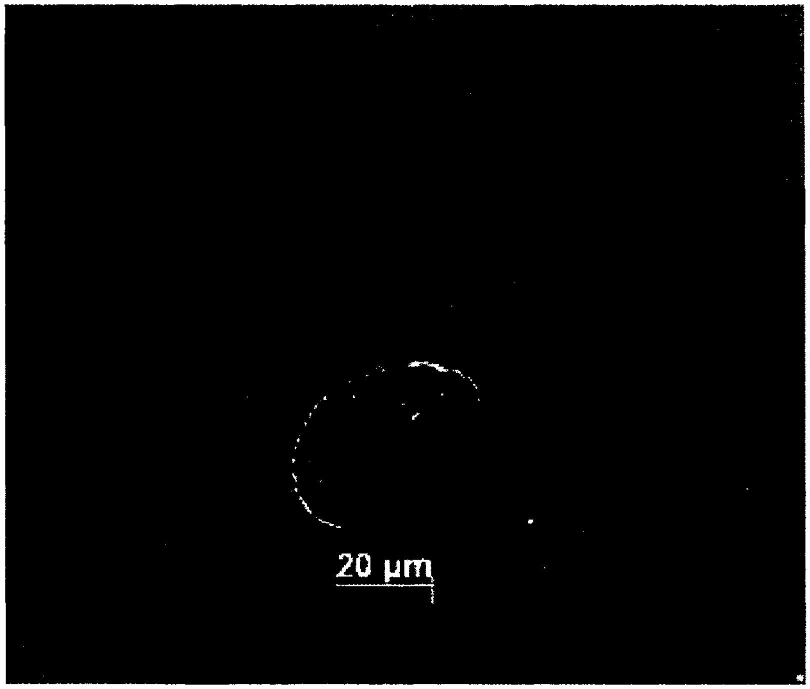

Figure 61.5: Damaged Starch Grain from pericarp of cf. *Solanum* (measurements)

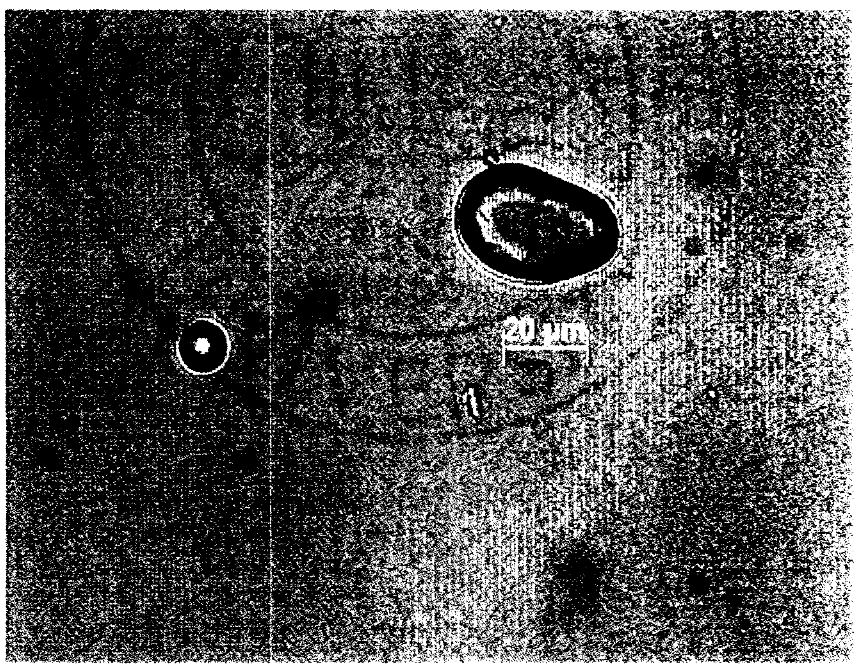

Figure 62.1: Starch grain from cf. *Cyperus*

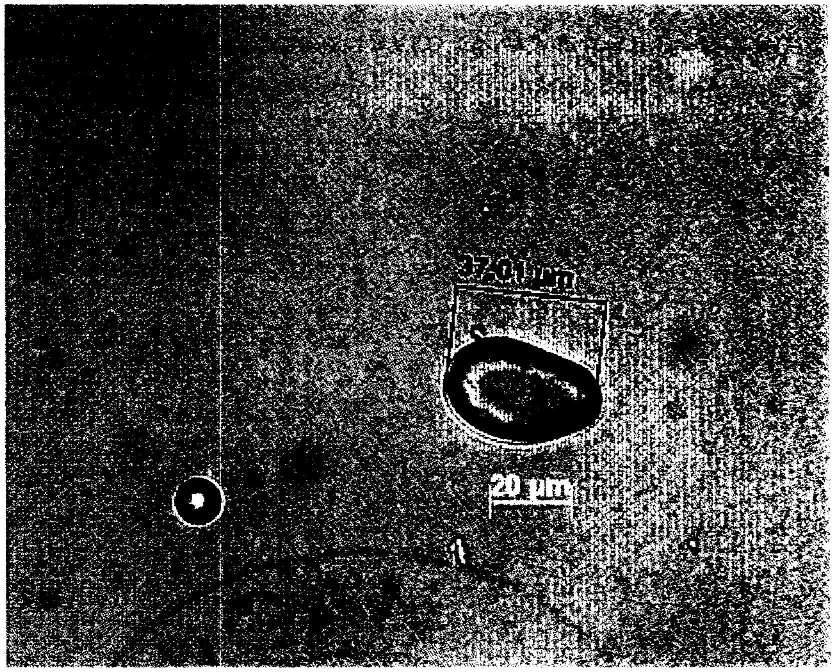

Figure 62.2: Starch grain from cf. *Cyperus* (measurements)

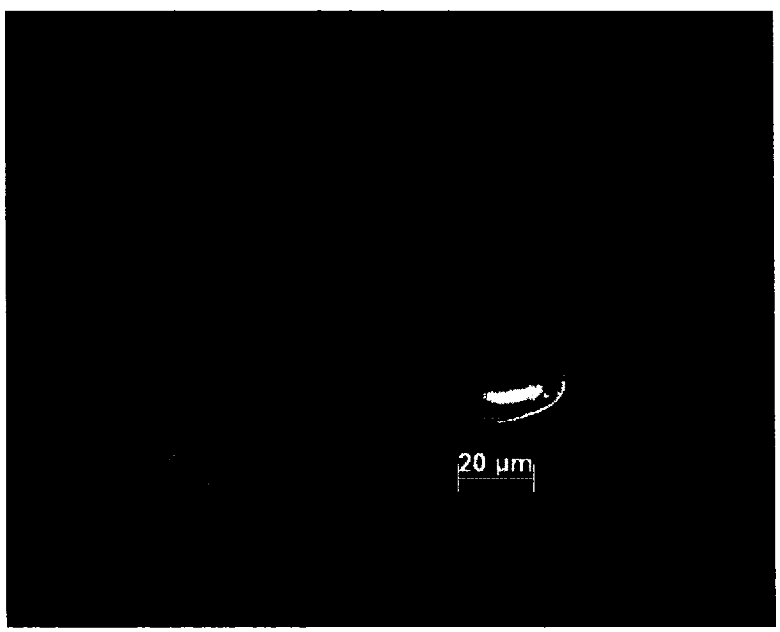

Figure 62.3: Starch grain from cf. *Cyperus* under Polarize Light

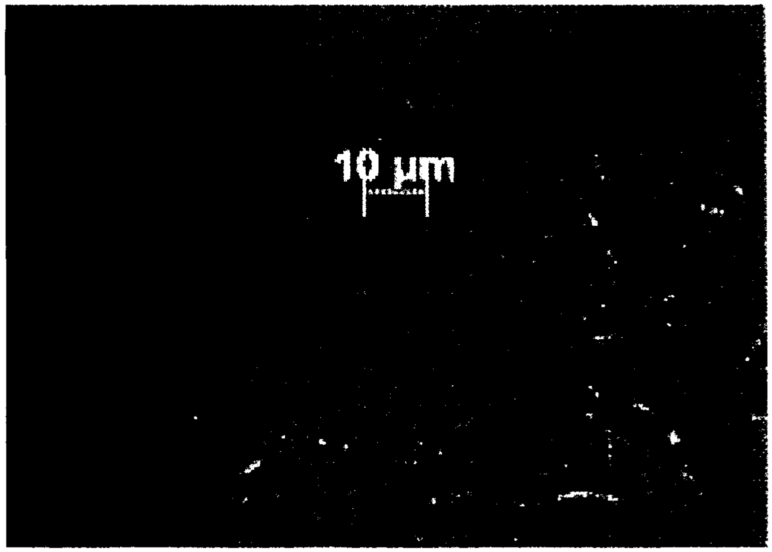

Figure 62.4: Starch grain from Seed of cf. *Solanum*

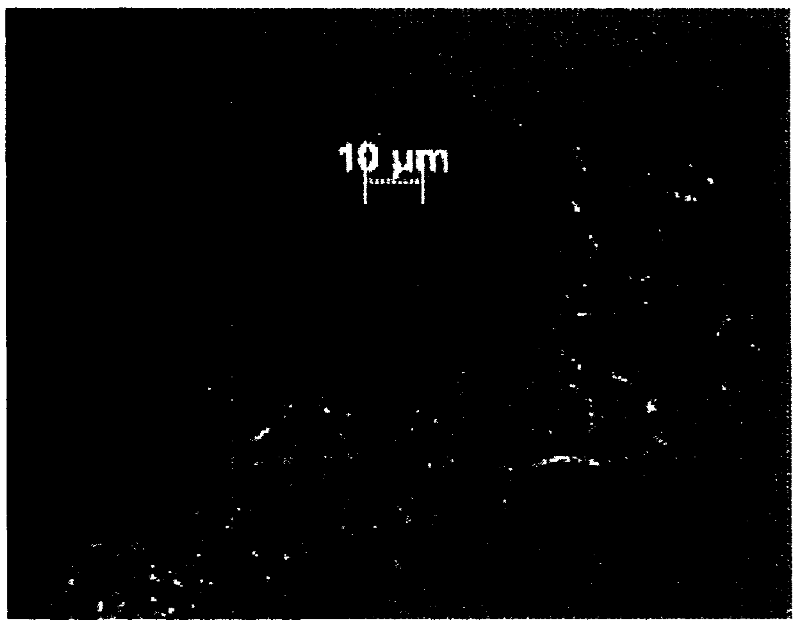

Figure 62.5: Starch grain from Seed of cf. *Solanum* (measurements)

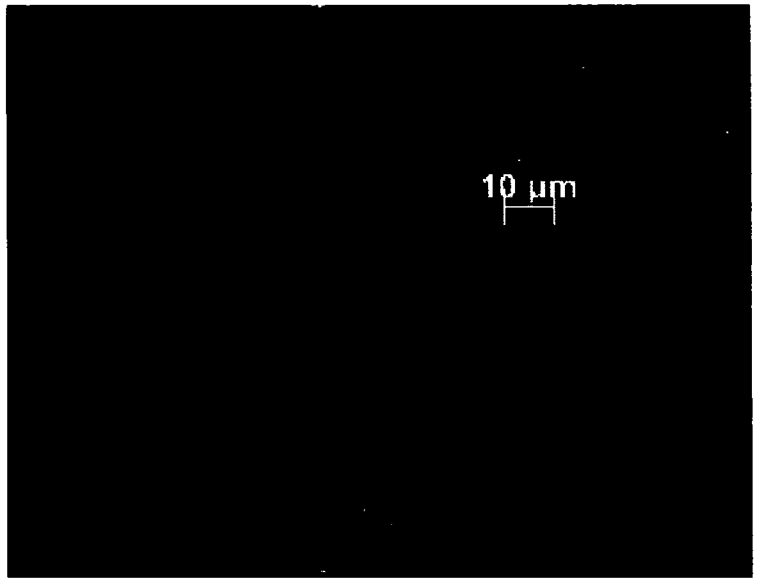

Figure 62.6: Starch grain from Seed of cf. *Solanum* under Polarize Light

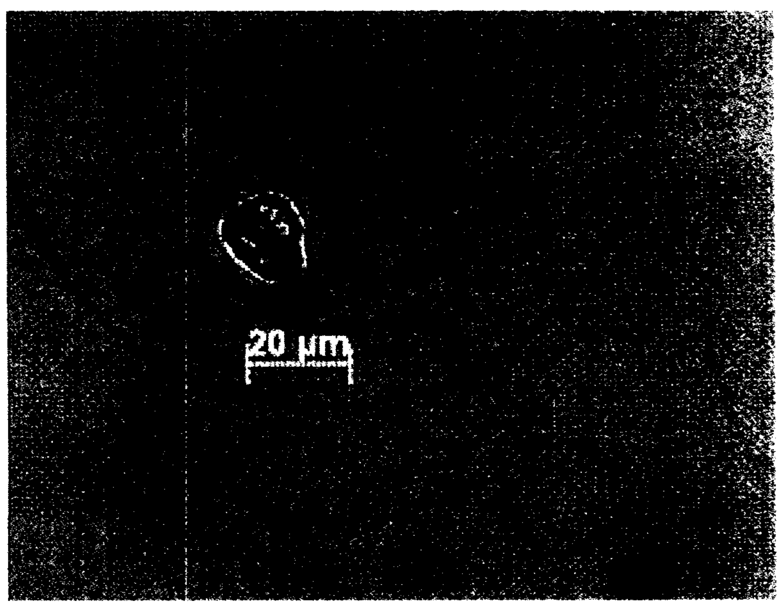

Figure 63.1: Unknown Damaged Starch 1

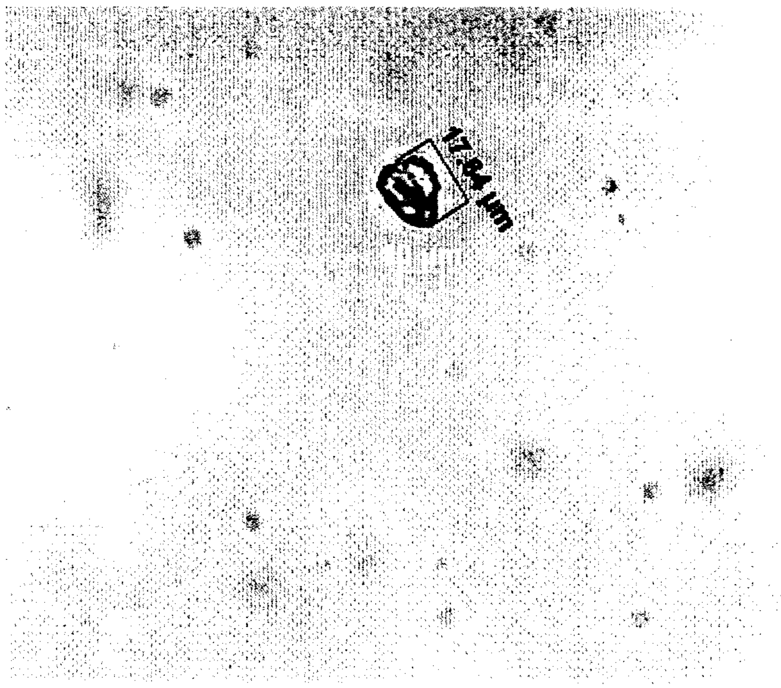

Figure 63.2: Unknown Damaged Starch 1 (measurements)

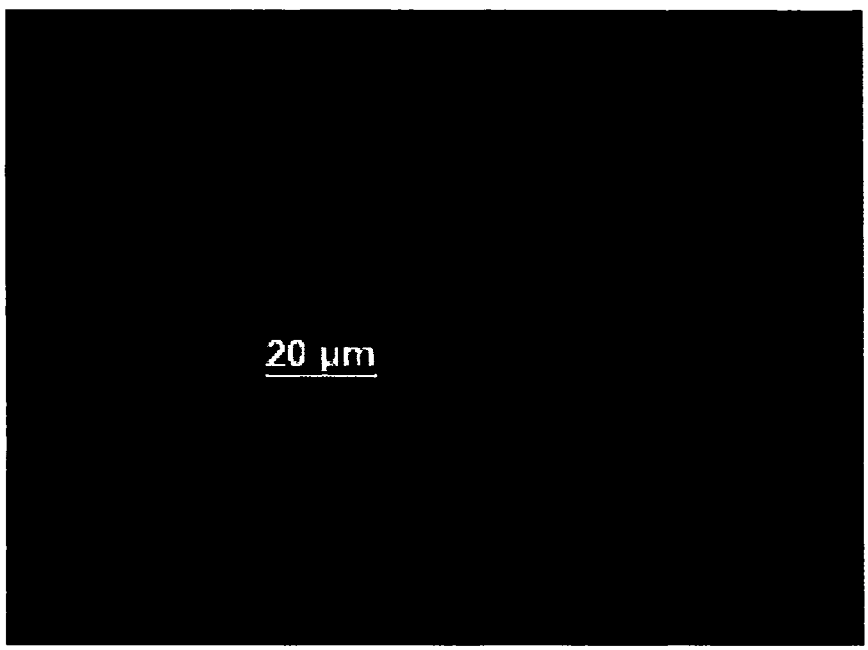

Figure 63.3: Unknown Damaged Starch 1 (under polarize light)

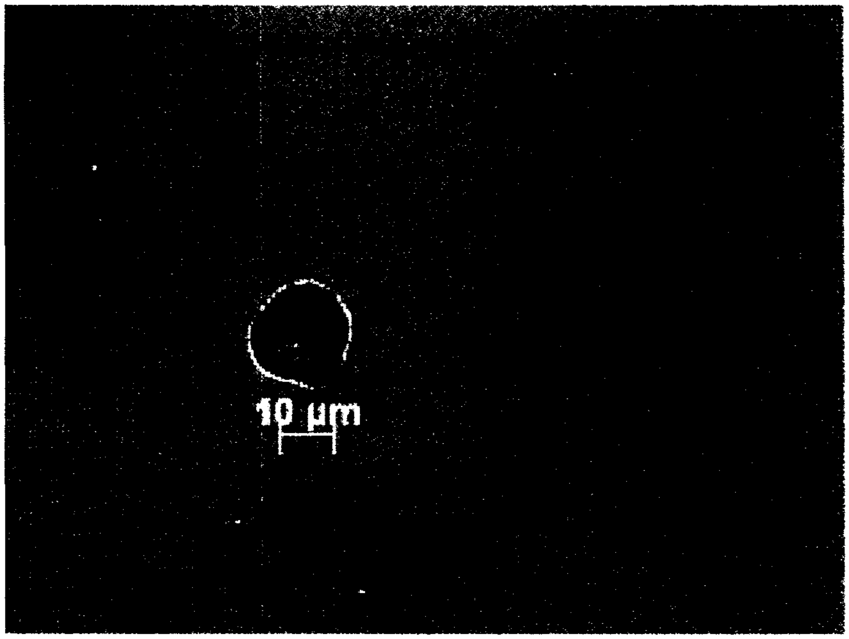

Figure 63.4: Unknown Damaged Starch 2

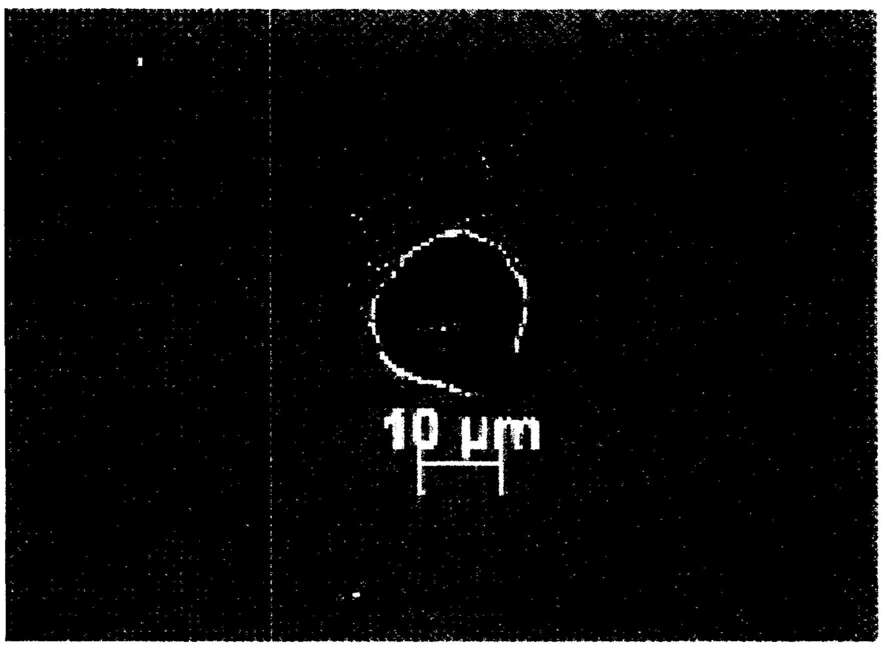

Figure 63.5: Unknown Damaged Starch 2 (measurement)

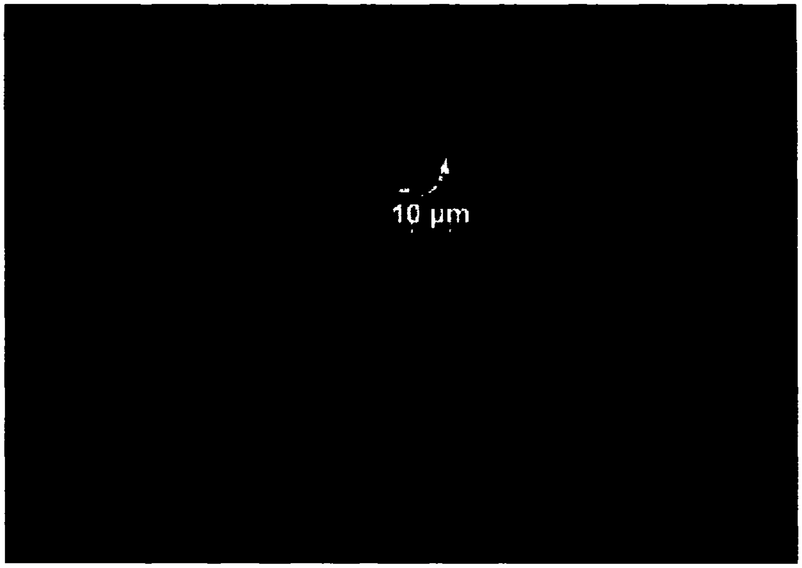

Figure 63.6: Unknown Damaged Starch 2 (under polarize light)

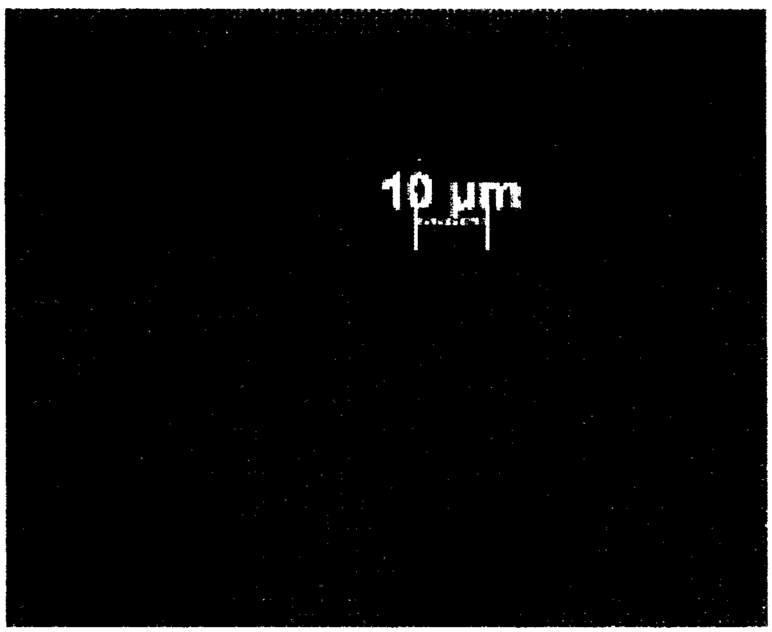

Figure 63.7: Compound Starch 1

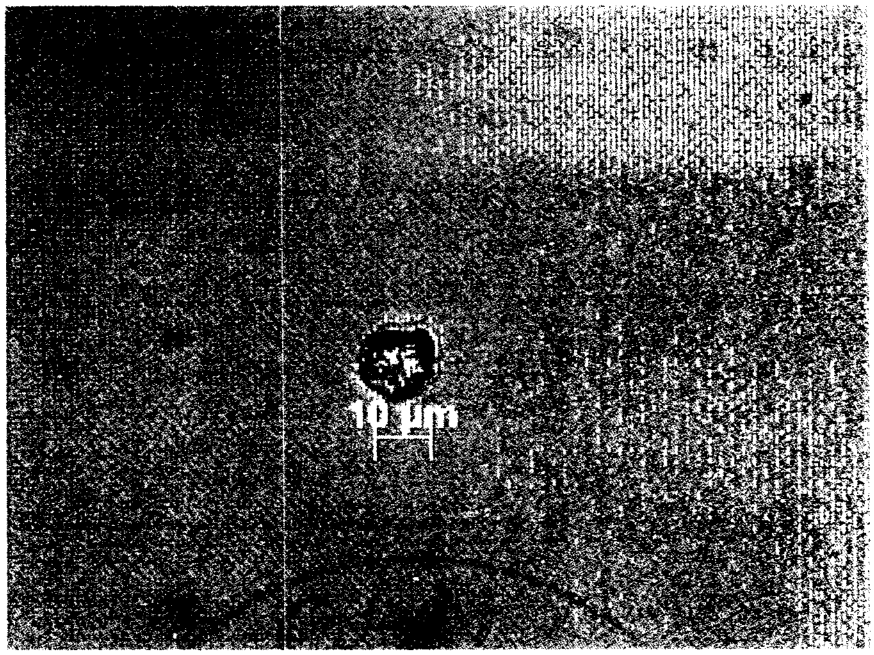

Figure 63.8: Unknown Damaged Starch 3

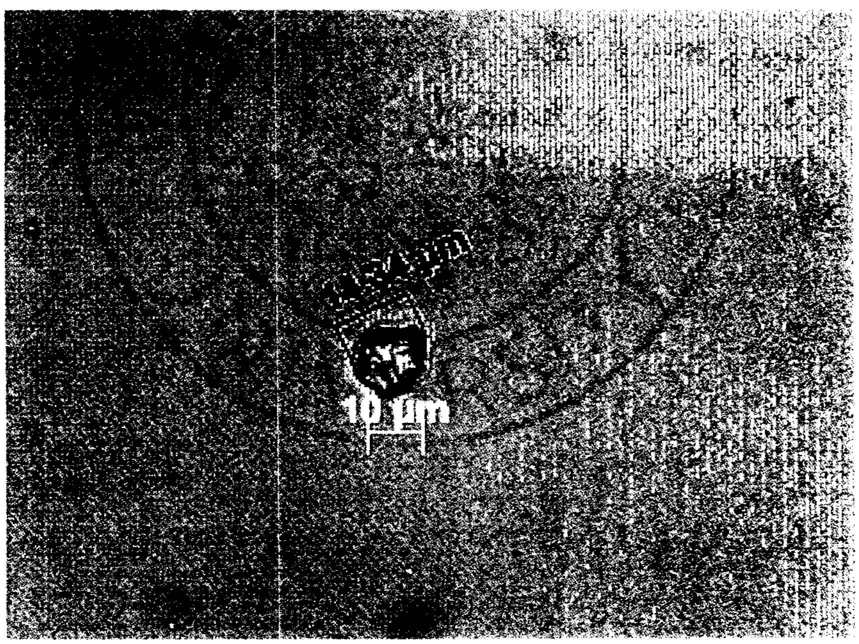

Figure 63.9: Unknown Damaged Starch 3 (measurement)

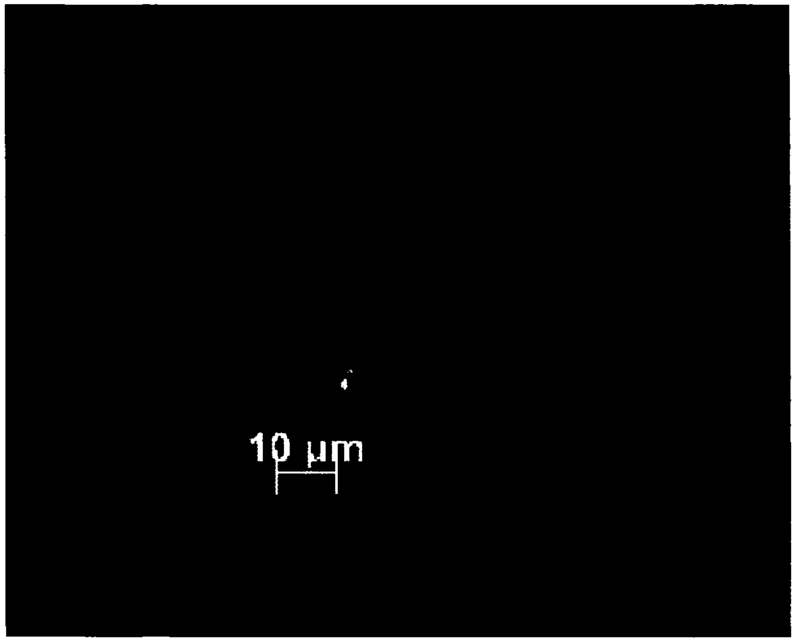

Figure 63.10: Unknown Damaged Starch 3 (under polarize light)

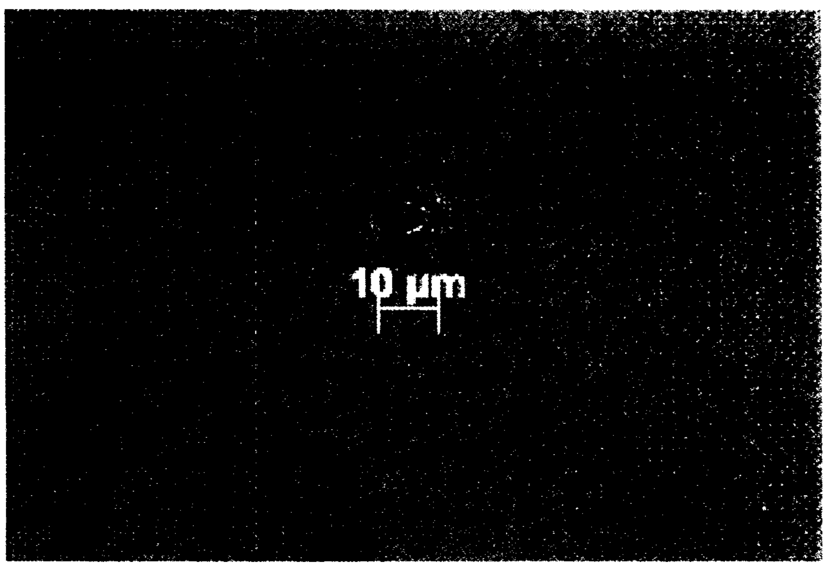

Figure 63.11: Compound Starch 2

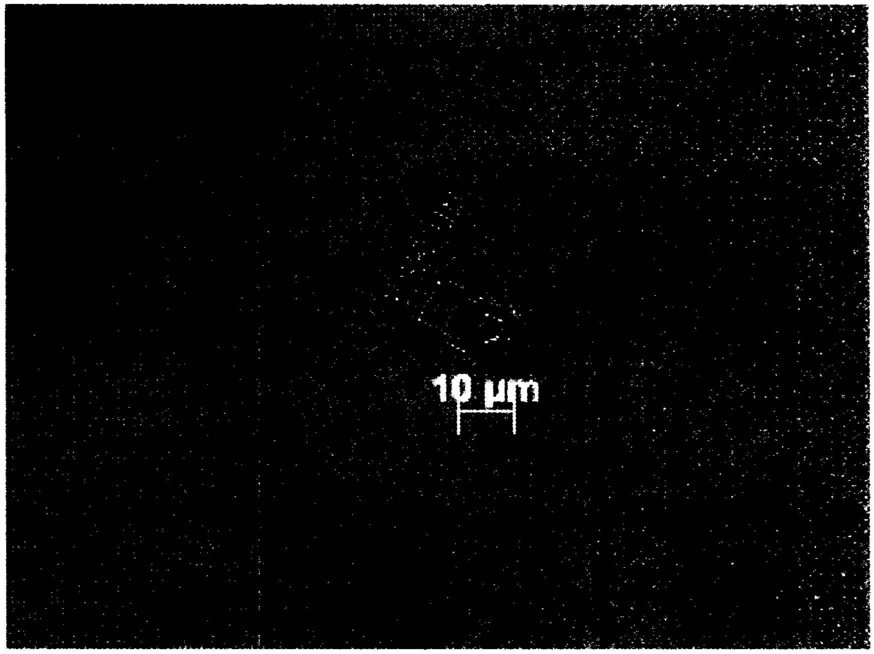

Figure 63.12: Compound Starch 2 (measurements)

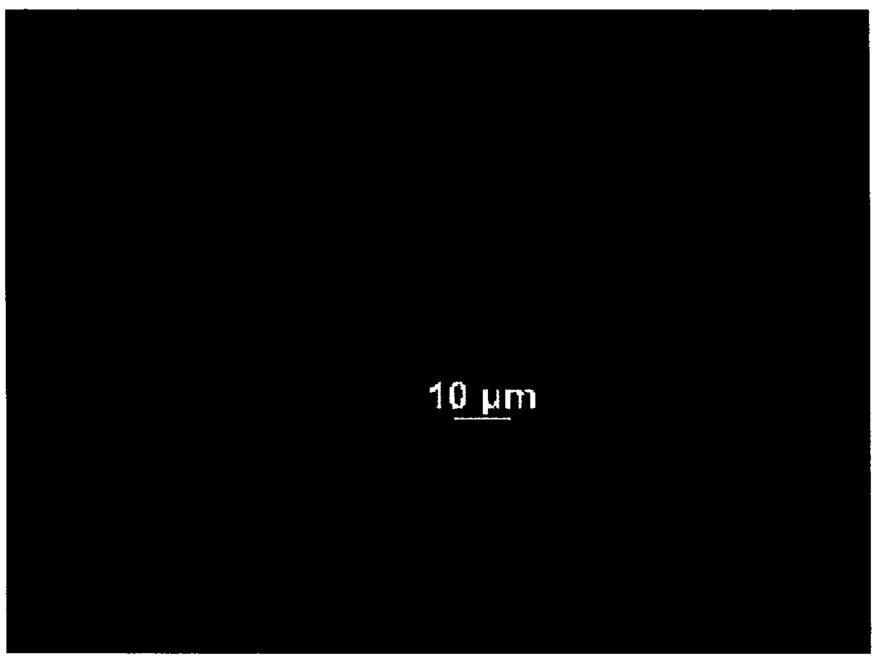

Figure 63.13: Compound Starch 2 (under polarize light)

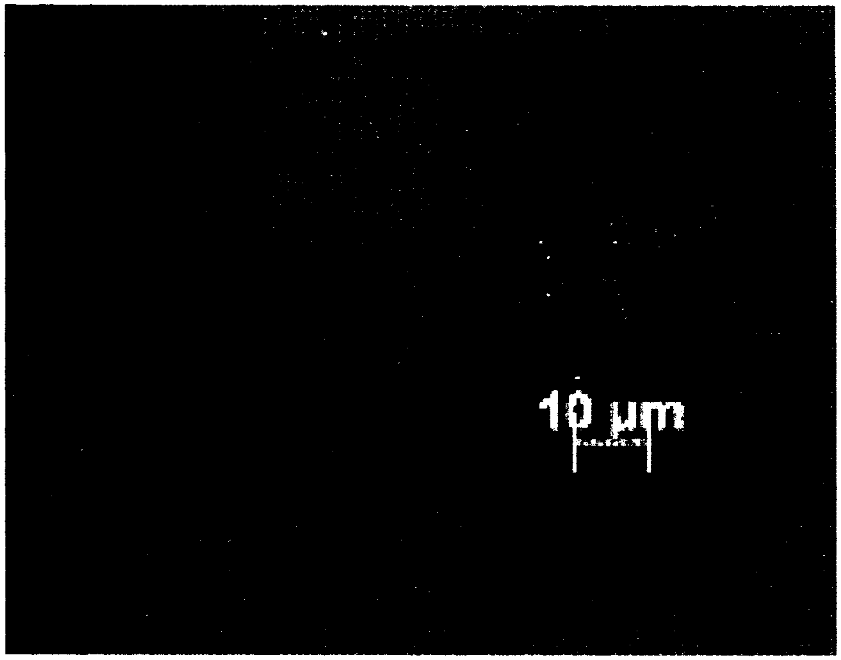

Figure 63.14: Compound Starch 1 (measurement)

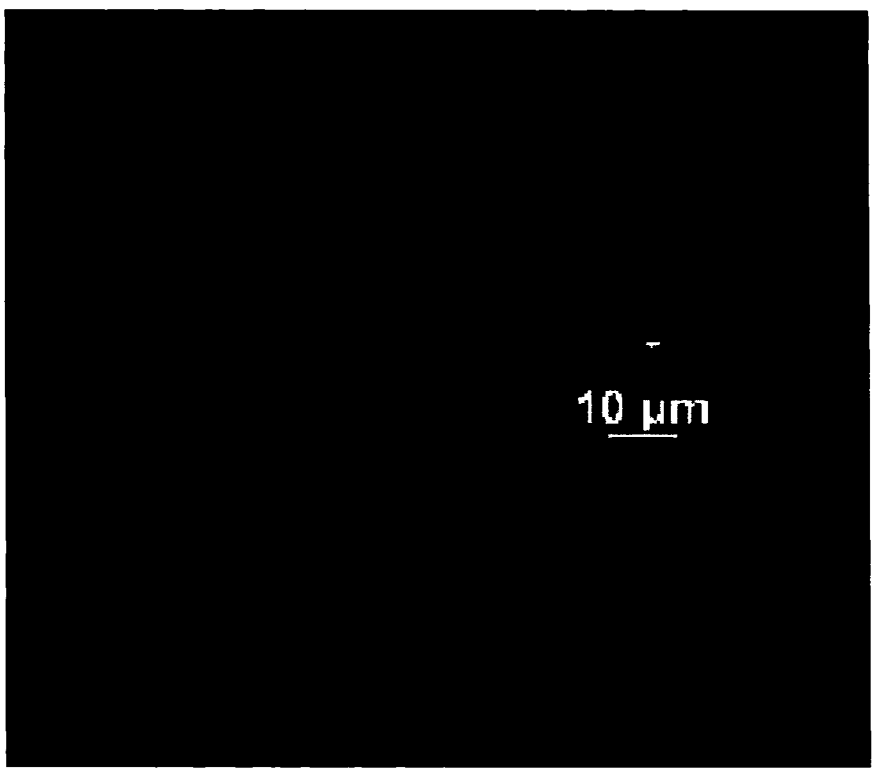

Figure 63.15: Compound Starch 1 (under polarize light)

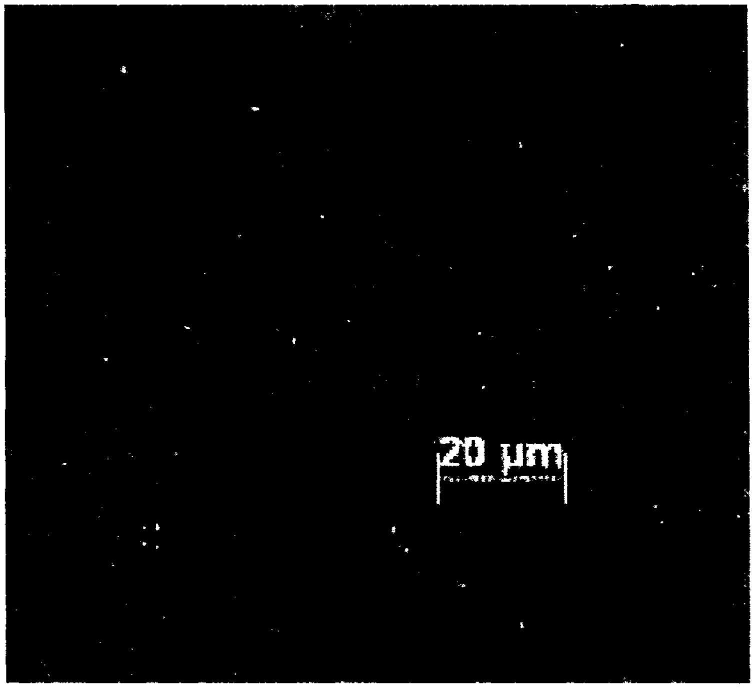

Figure 64.1 Spherical Starch Consistent with cf. *Mangifera*

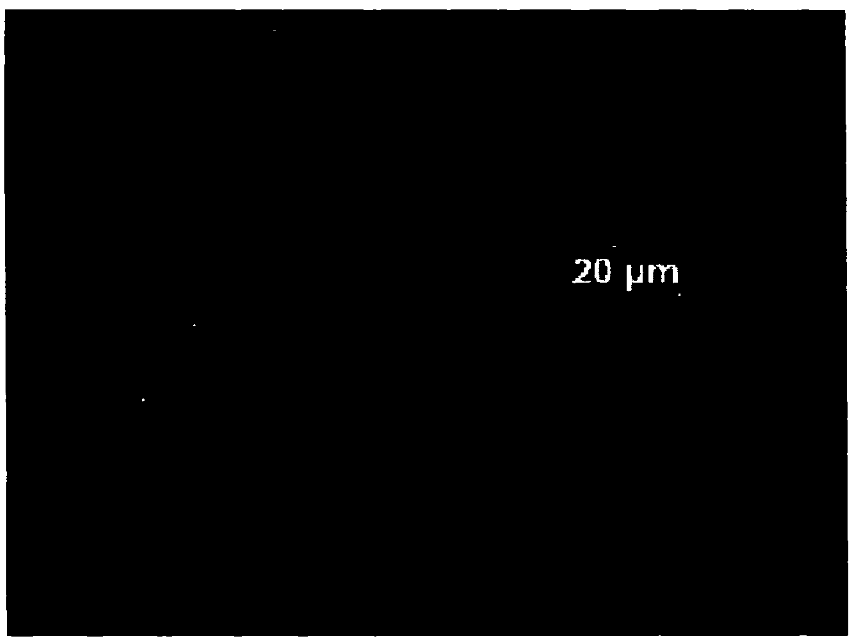

Figure 64.2: Spherical Starch Consistent with cf. *Mangifera* (under polarize light)

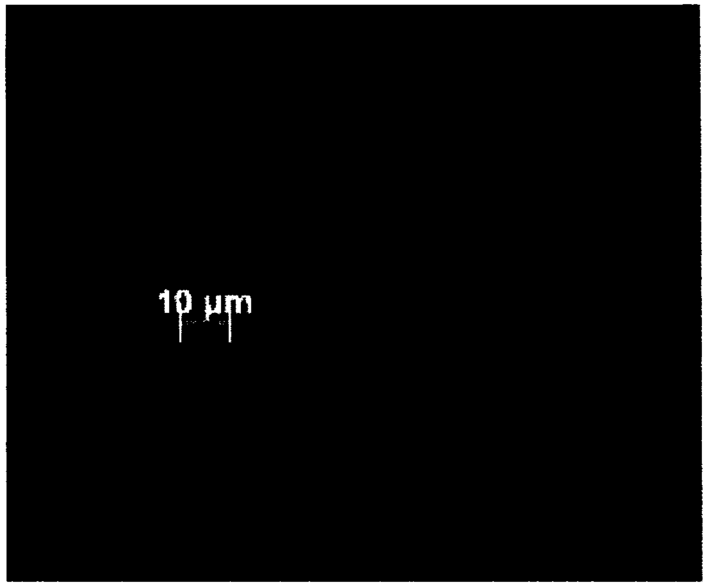

Figure 64.3: Compound Starch

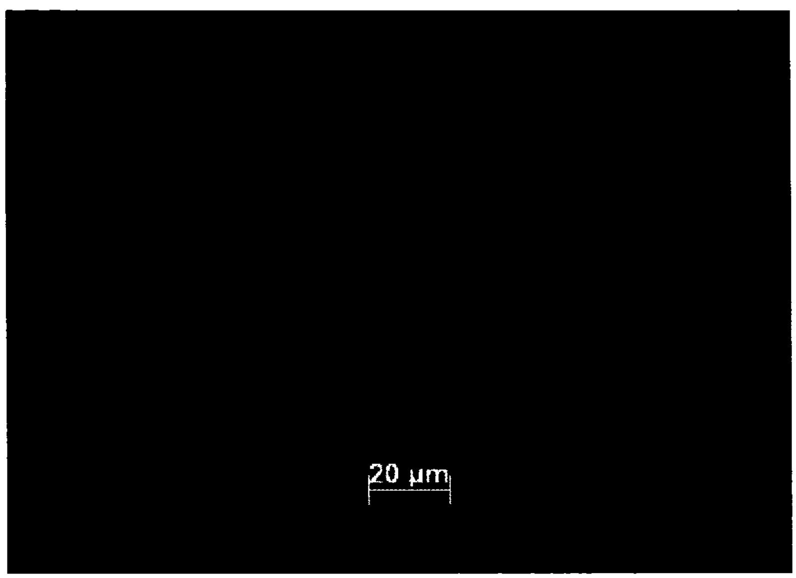

Figure 65.1: Bean Starch

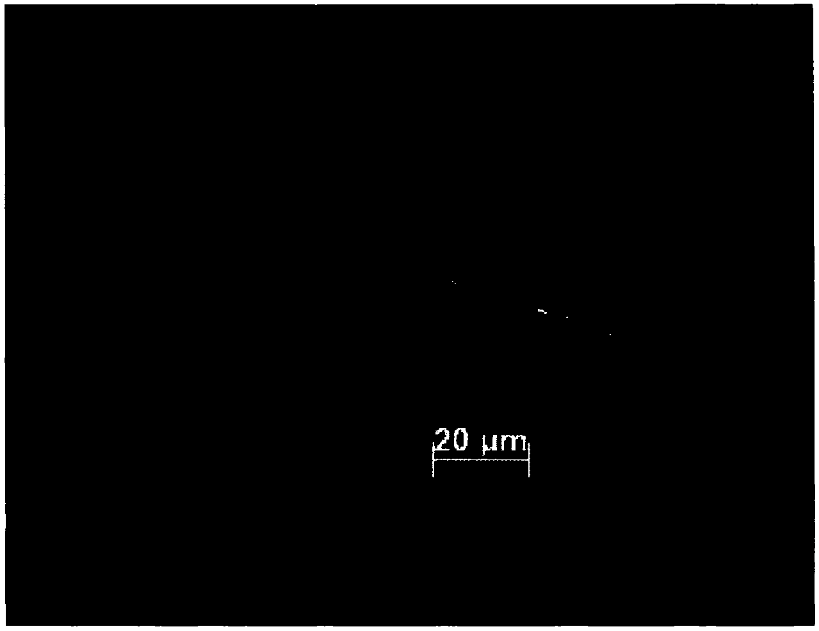

Figure 65.2: Bean Starch (under polarize light)

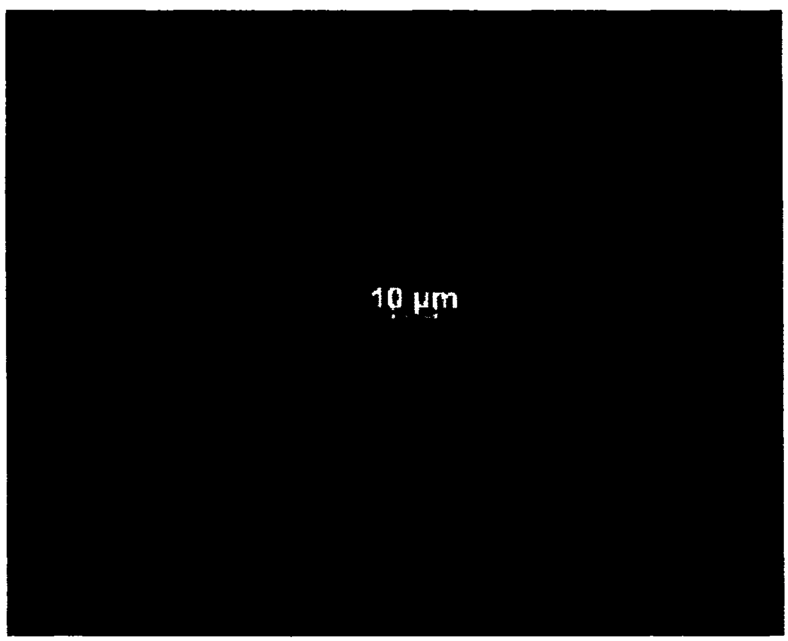

Figure 65.3: Cluster of Compound Starches

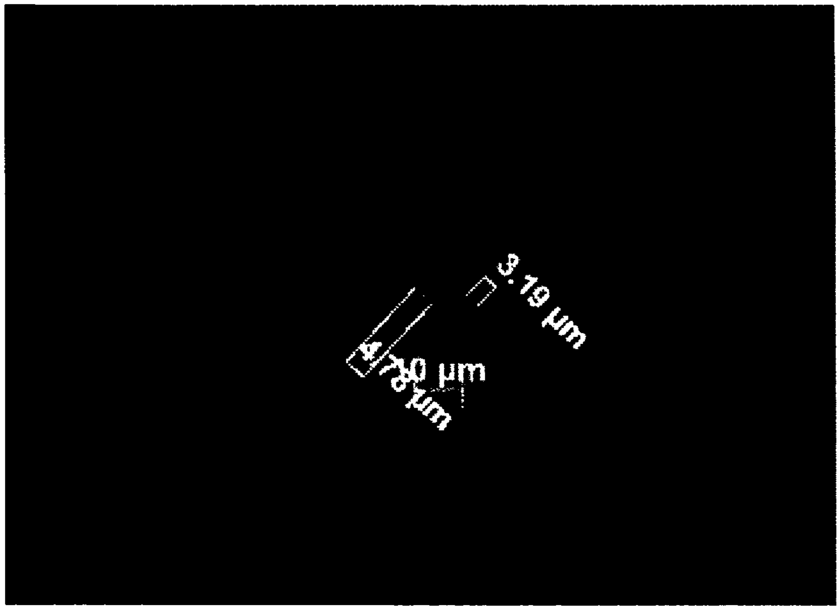

Figure 65.4: Cluster of Compound Starch (measurement)

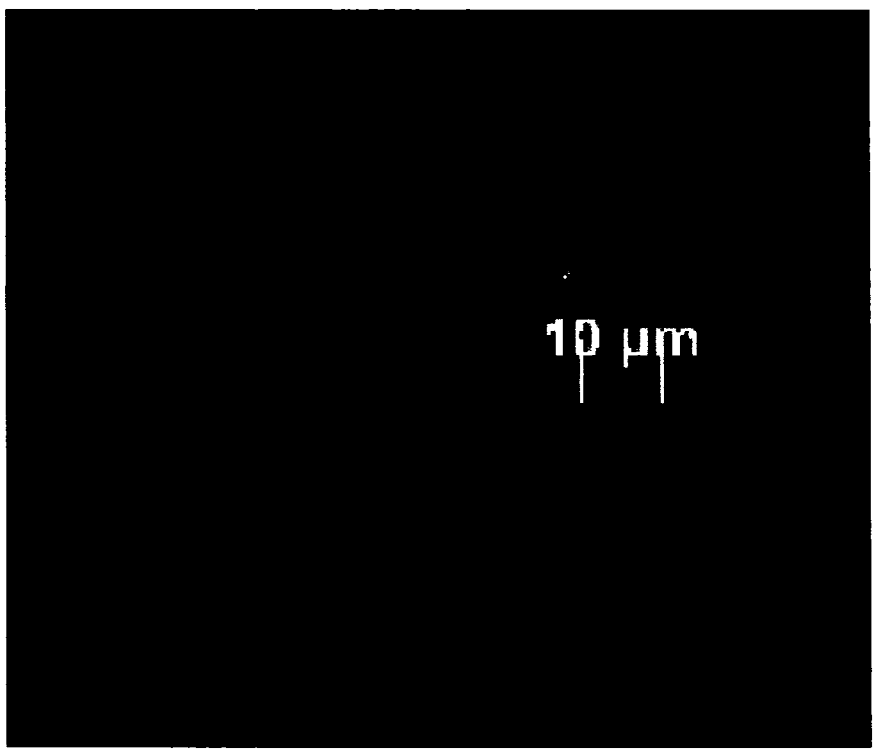

Figure 65.5: Cluster of Compound Starch (under polarize light)

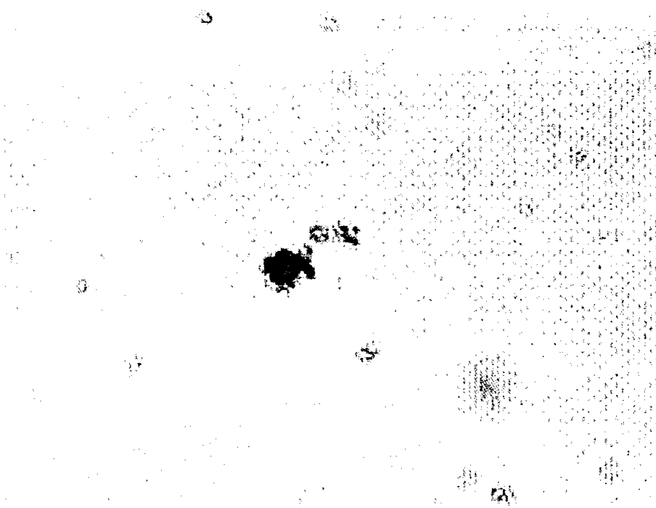

Figure 66.1: Compound Starch 1 (measurement)

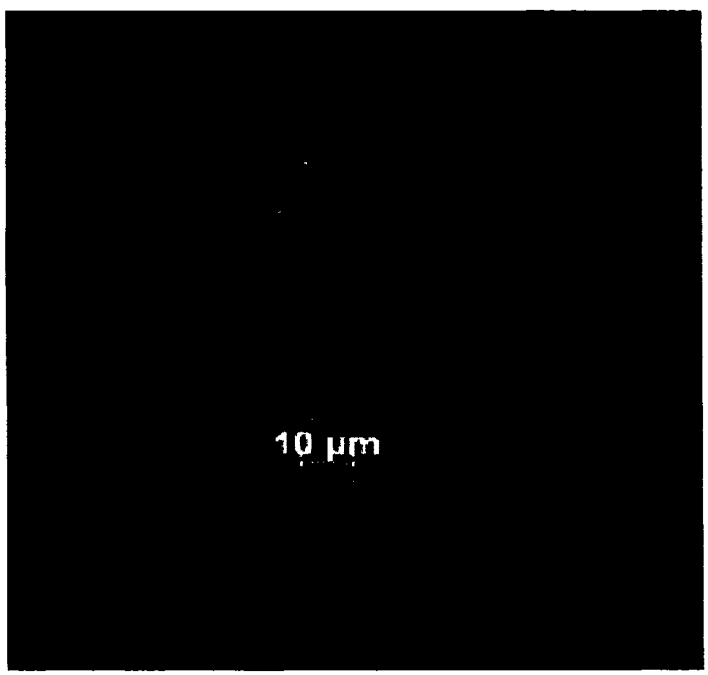

Figure 66.2: Compound Starch 2

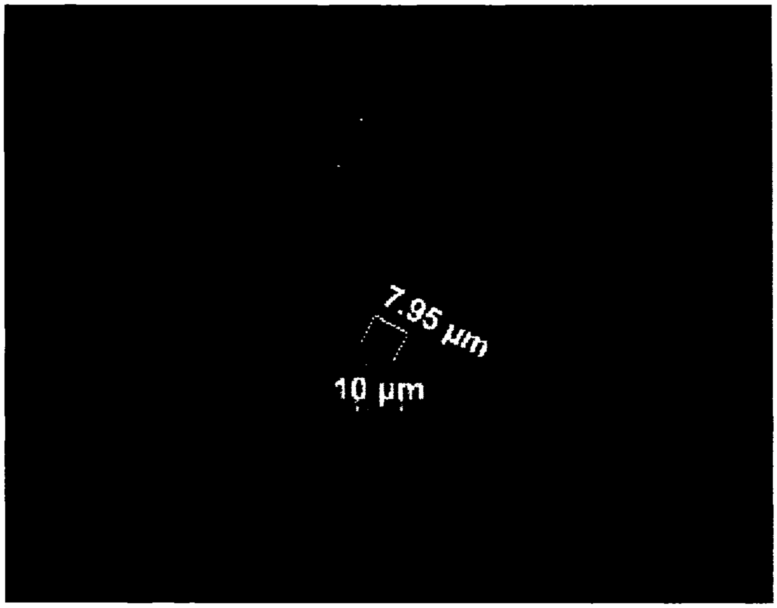

Figure 66.3: Compound Starch 2 (measurement)

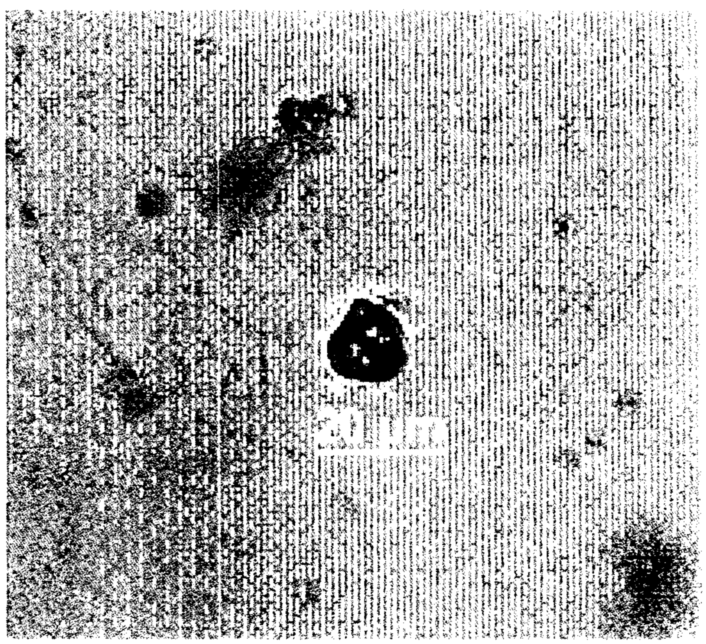

Figure 66.4: Unknown Starch

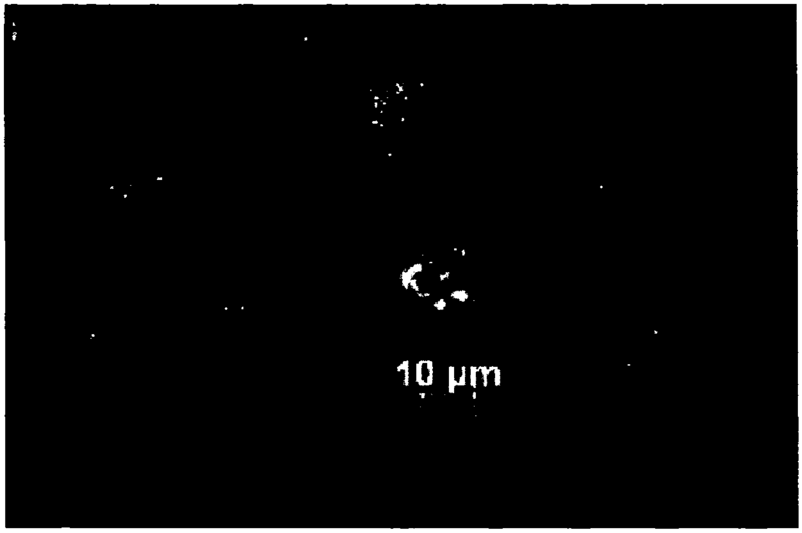

Figure 66.5: Unknown Starch (under polarize light)

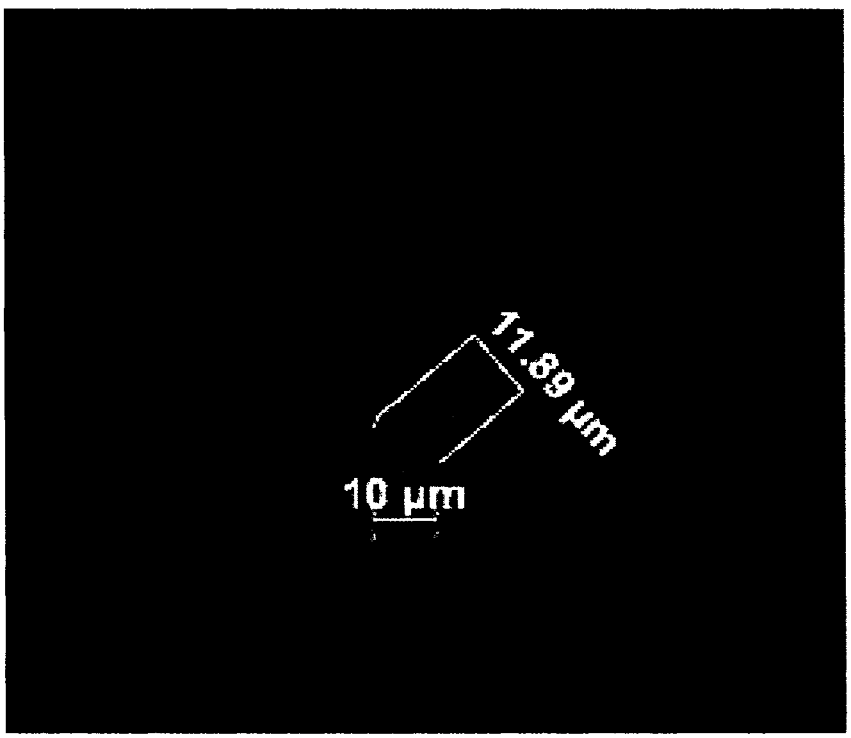

Figure 66.6: Unknown Starch (measurement)

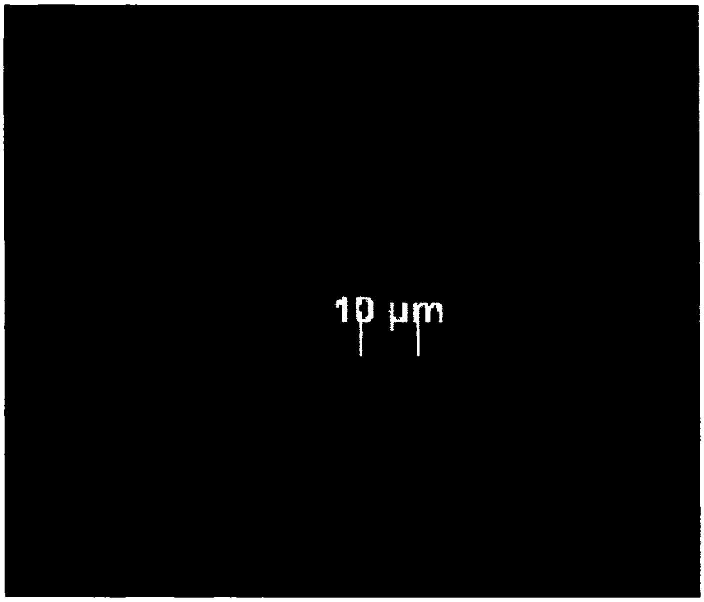

Figure 67.1: Unknown Starch

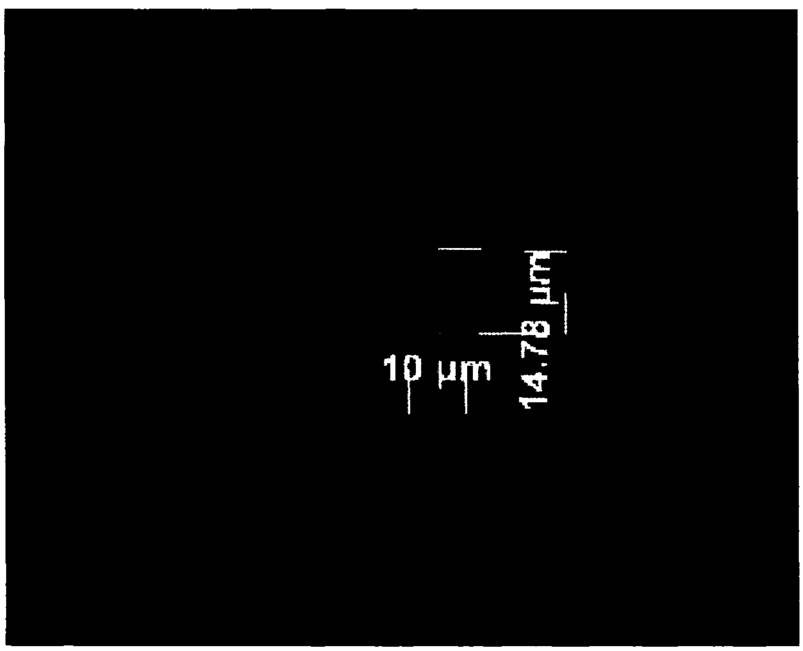

Figure 67.2: Unknown Starch (measurement)

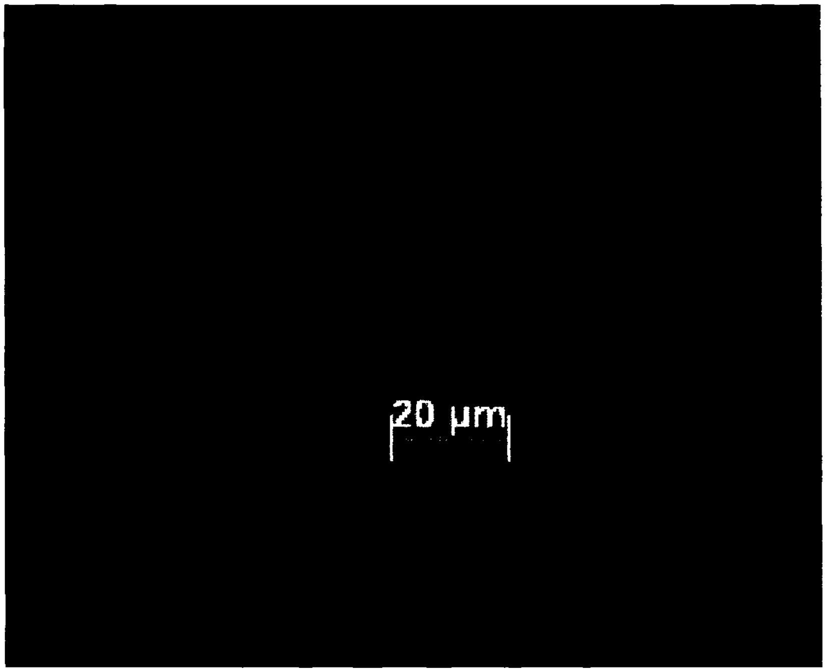

Figure 67.3: Damaged Bean Starch

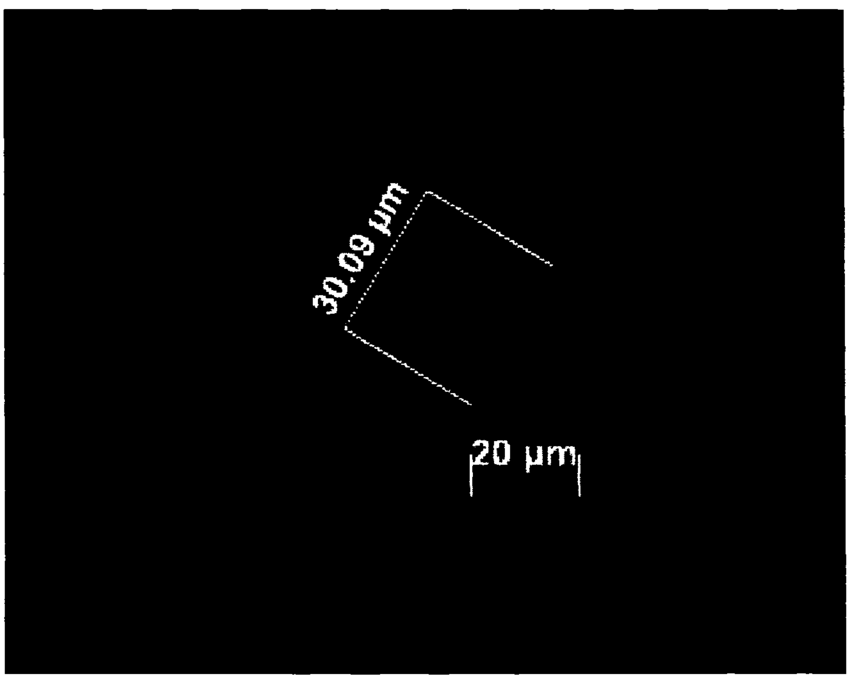

Figure 67.4: Damaged Bean Starch (measurement)

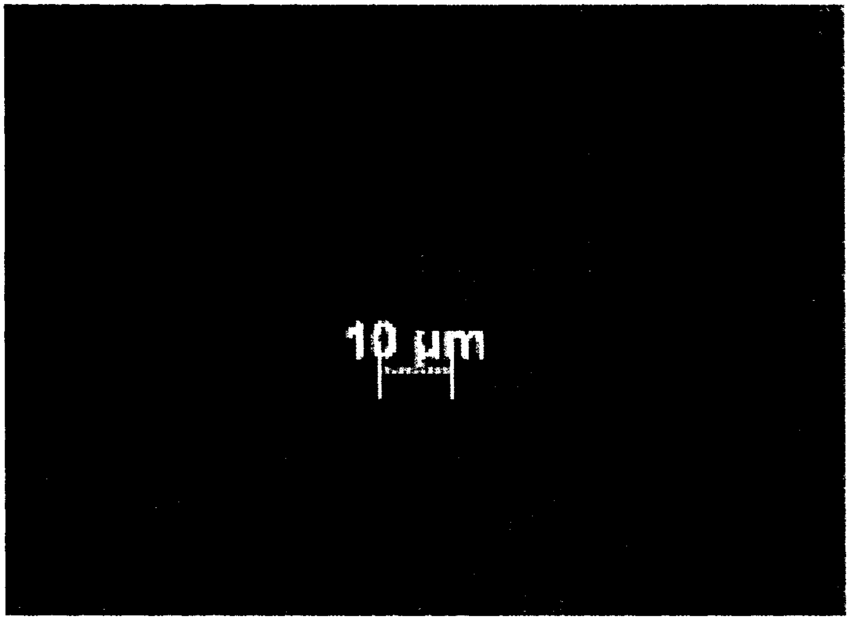

Figure 68.1: Compound Starch 1

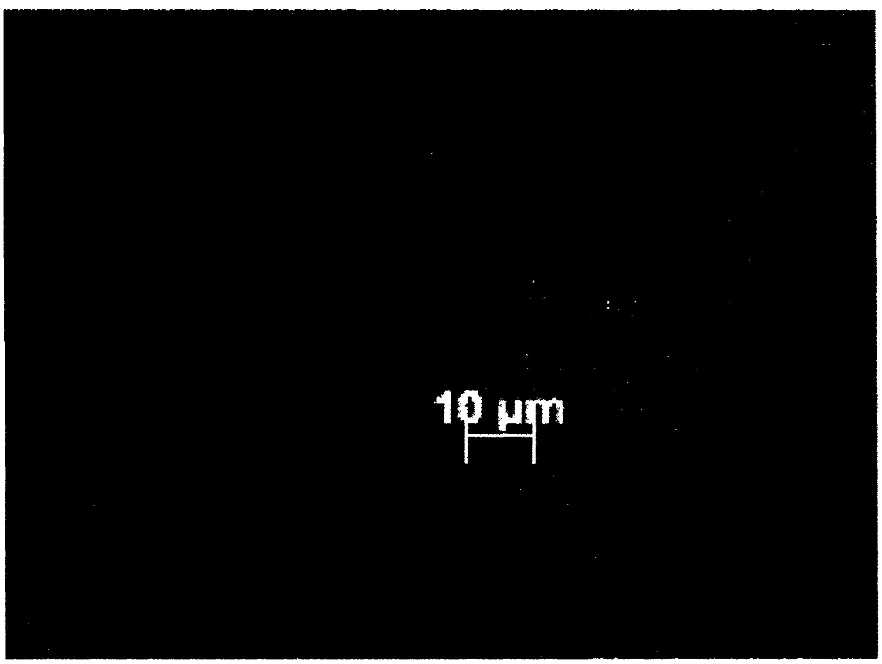

Figure 68.2: Compound Starch 1 (measurement)

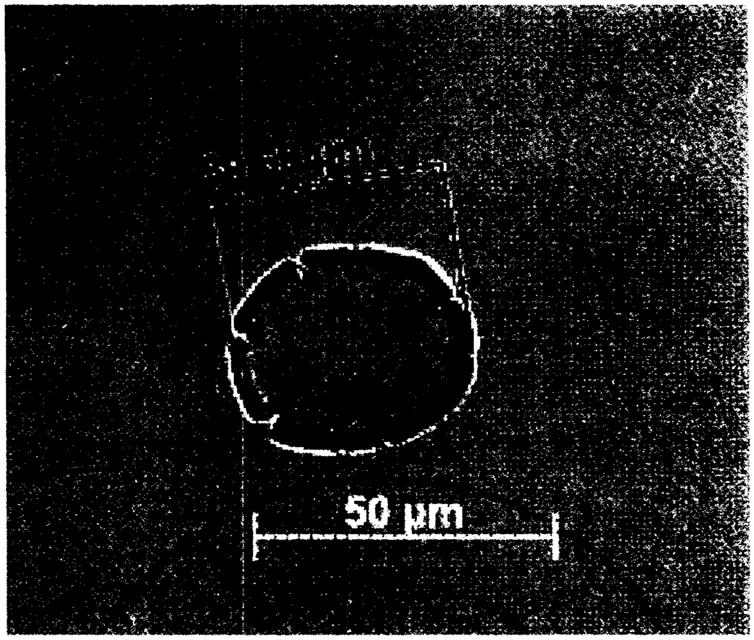

Figure 68.3: Damaged Starch consistent with cf. *Solanum*

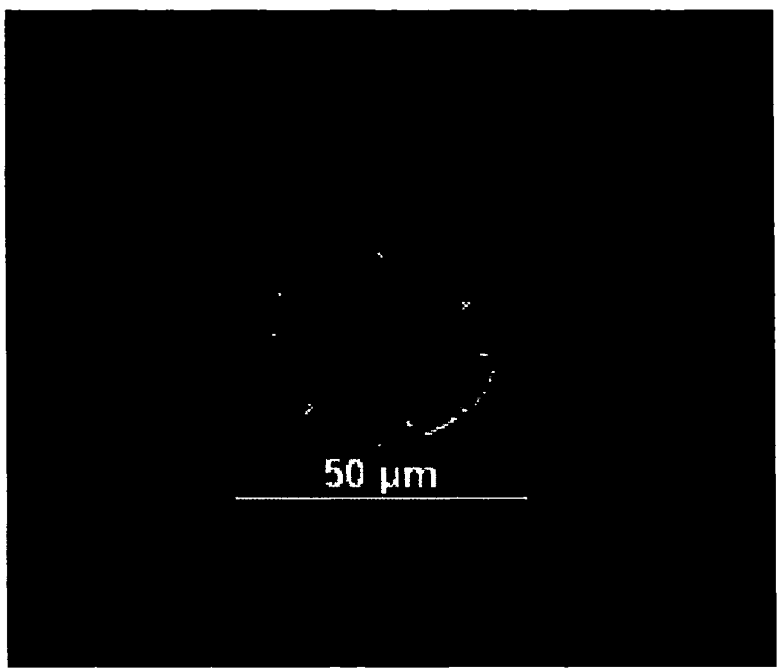

Figure 68.4: Damaged Starch consistent with cf. *Solanum* (under polarize light)

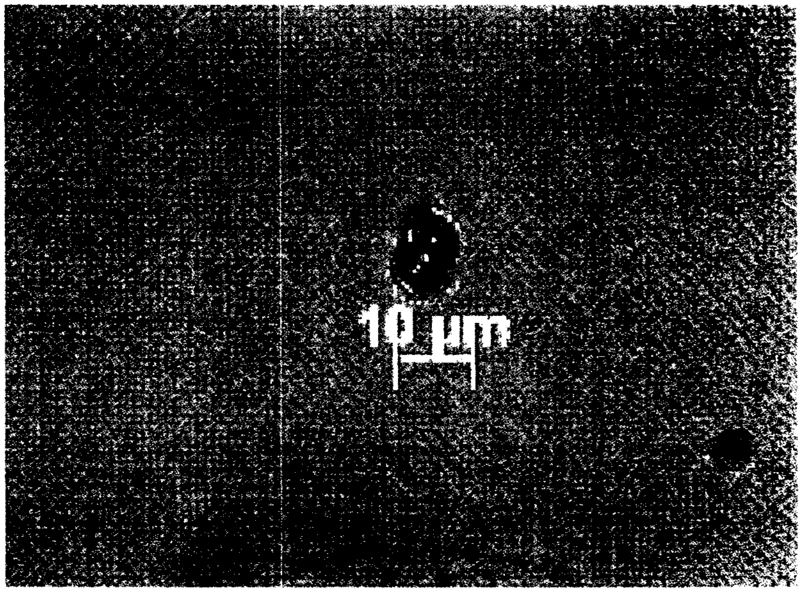

Figure 68.5: Compound Starch 2

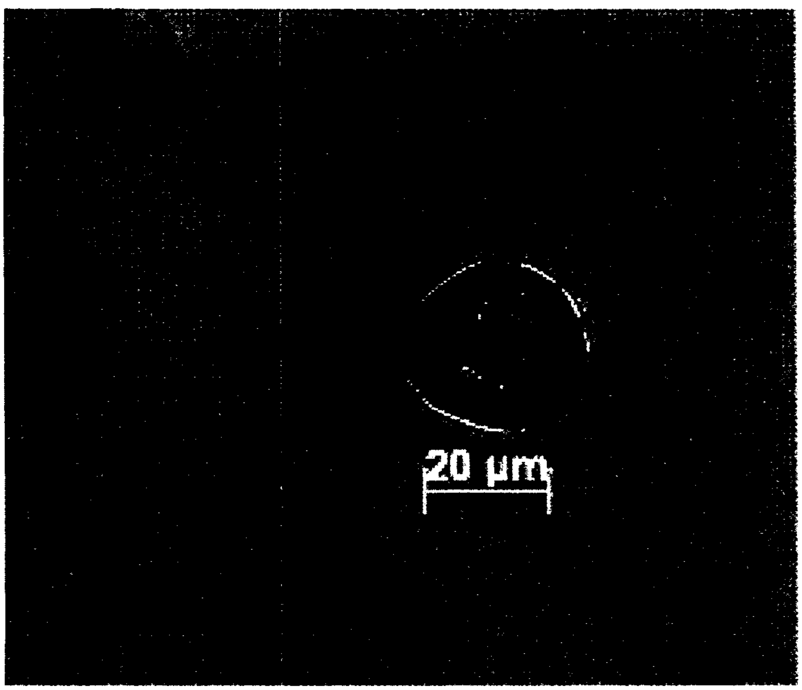

Figure 69.1: Spherical Starch from cf. *Macrotyloma*

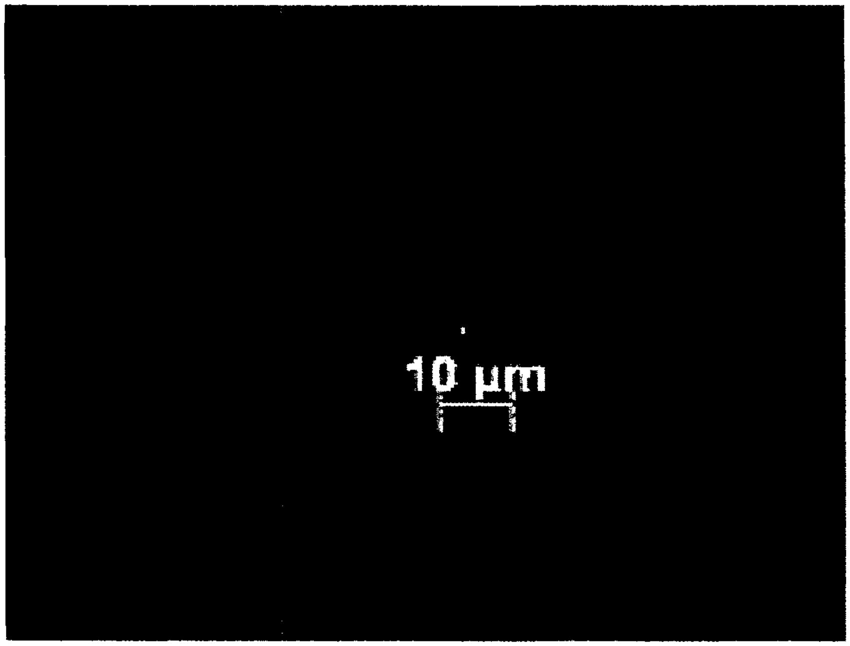

Figure 69.2: Starch Grains from cf. *Sesamum*

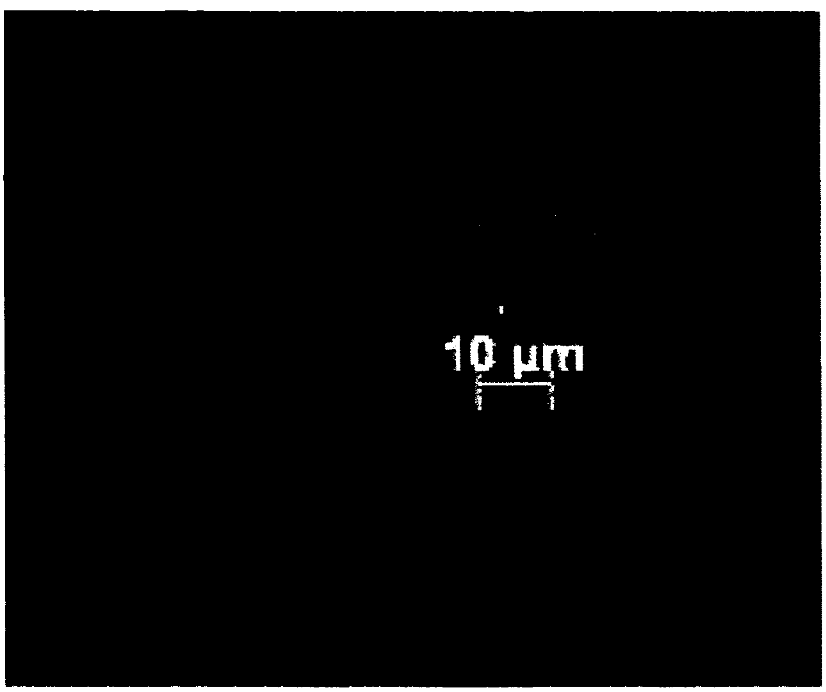

Figure 69.3: Starch Grains from cf. *Sesamum* (measurement)

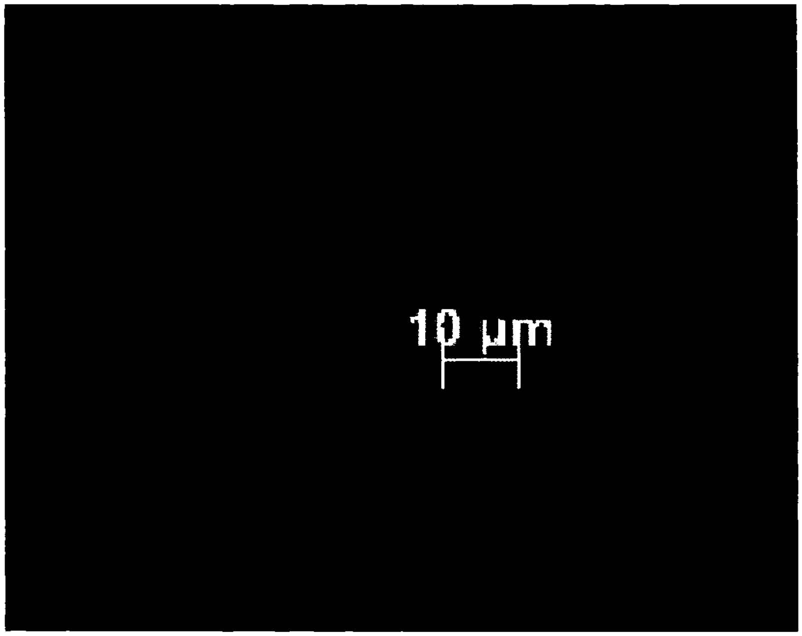

Figure 69.4: Starch Grains from cf. *Sesamum* (under polarize light)

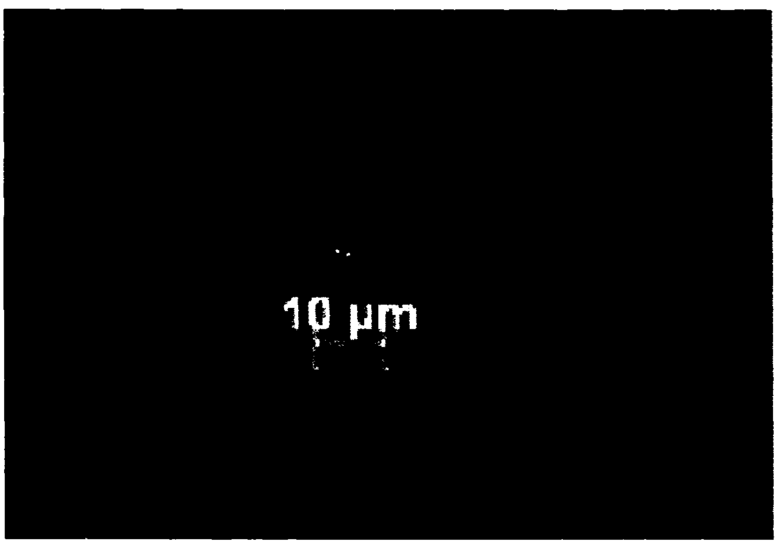

Figure 69.5: Starch Grains from cf. *Sesamum*

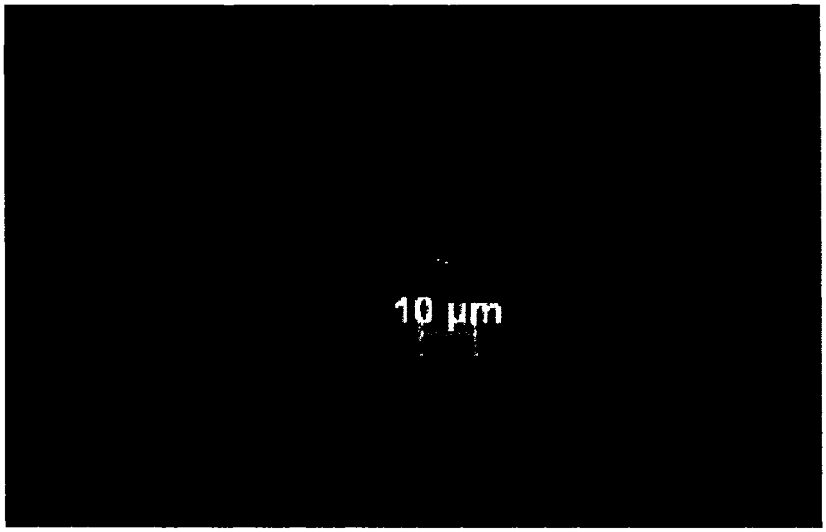

Figure 69.6 Starch Grains from cf. *Sesamum*

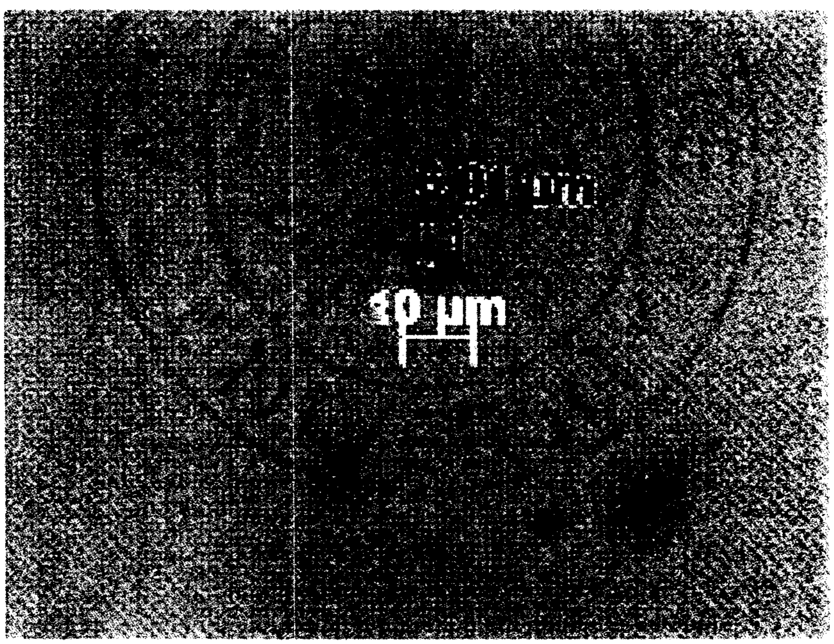

Figure 69.7: Starch Grains from cf. *Sesamum* (measurement)

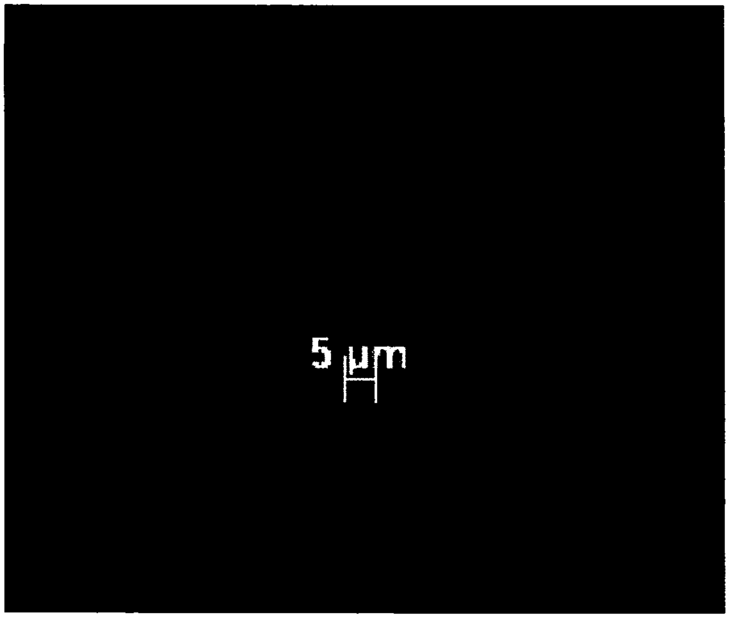

Figure 69.8: Starch Grains from cf. *Sesamum*

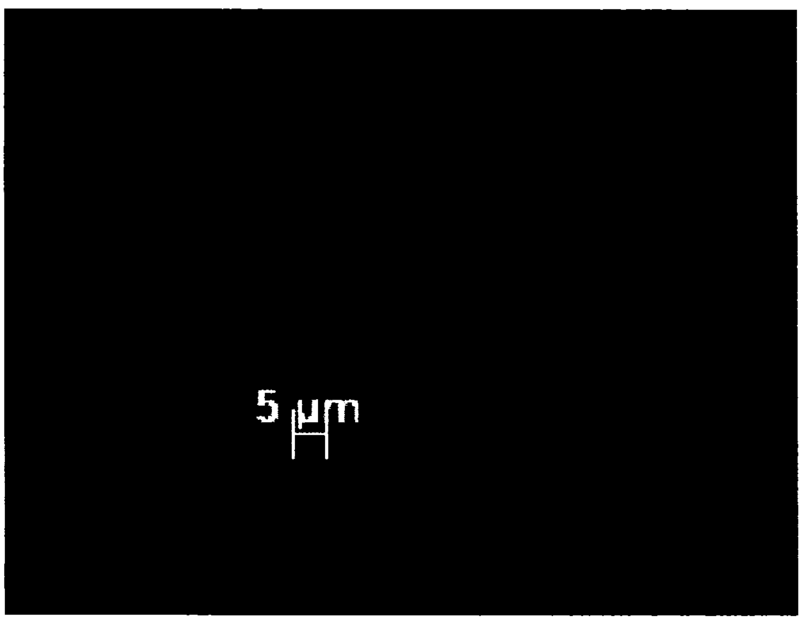

Figure 69.9: Starch Grains from cf. *Sesamum*

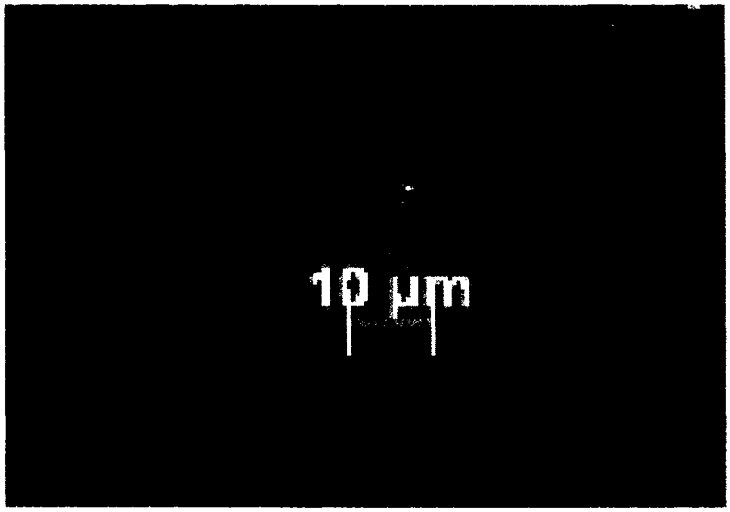

Figure 69.10: Starch Grains from cf. *Sesamum*

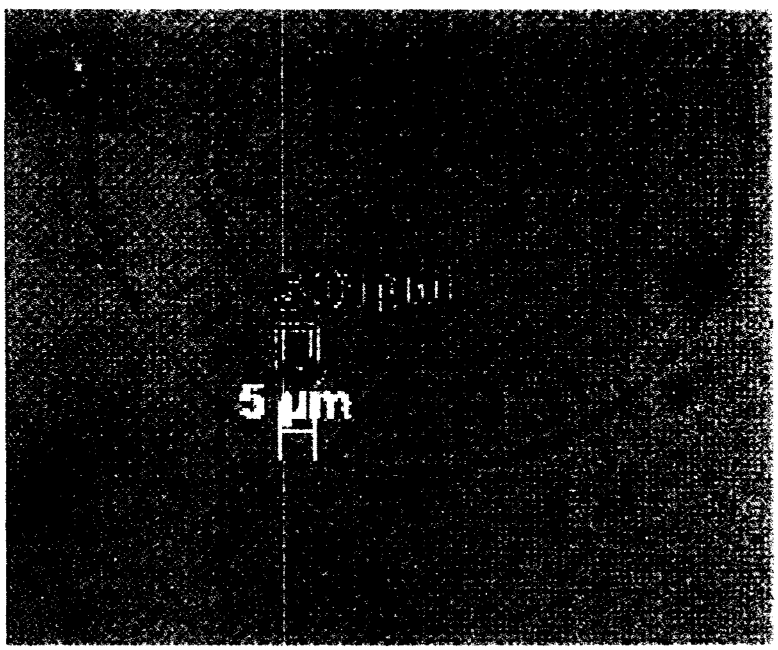

Figure 69.11: Starch Grains from cf. *Sesamum*

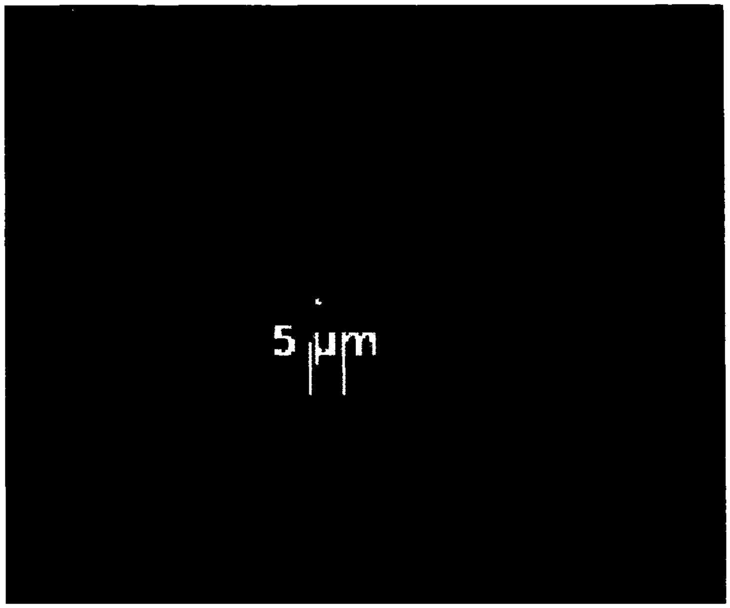

Figure 69.12: Starch Grains from cf. *Sesamum* (under polarize light)

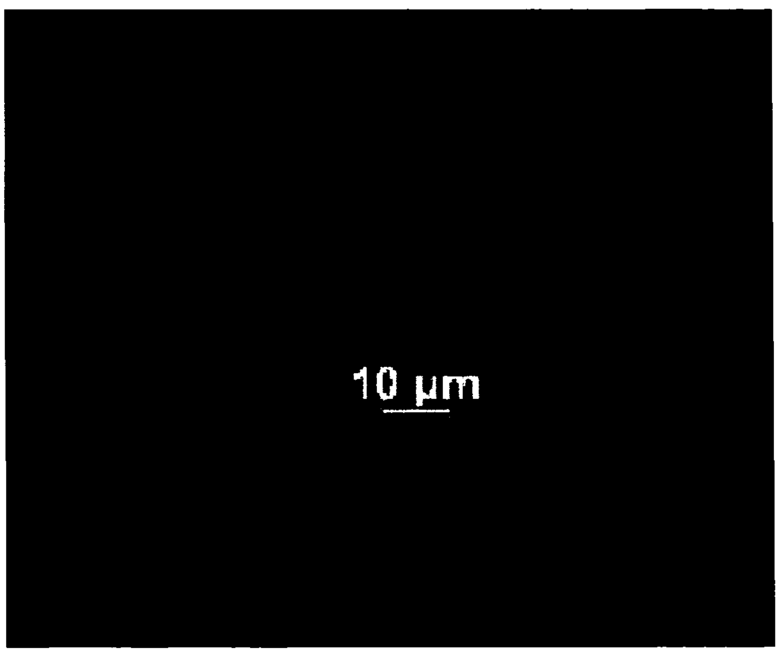

Figure 69.13: Starch Grain Consistent with cf. *Mangifera*

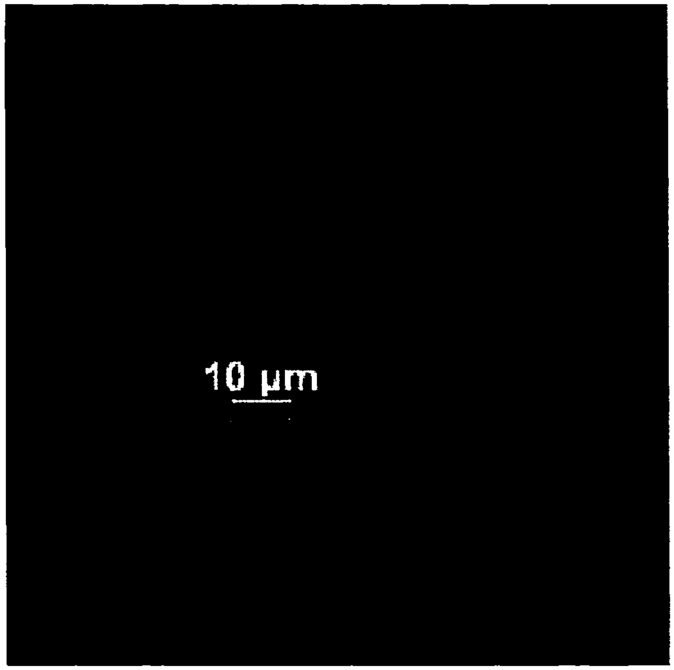

Figure 69.14: Starch Grain Consistent with cf. *Mangifera* (measurement)

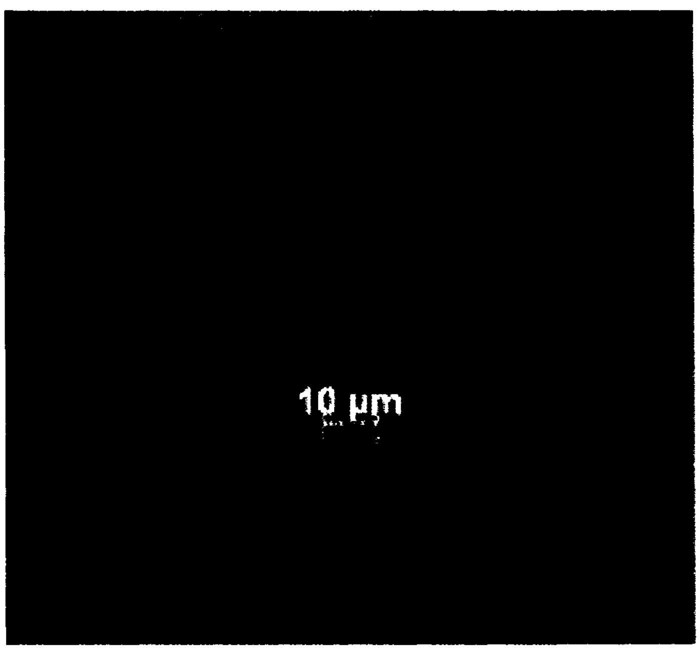

Figure 69.15: Starch Grain Consistent with cf. *Mangifera* (on rotation)

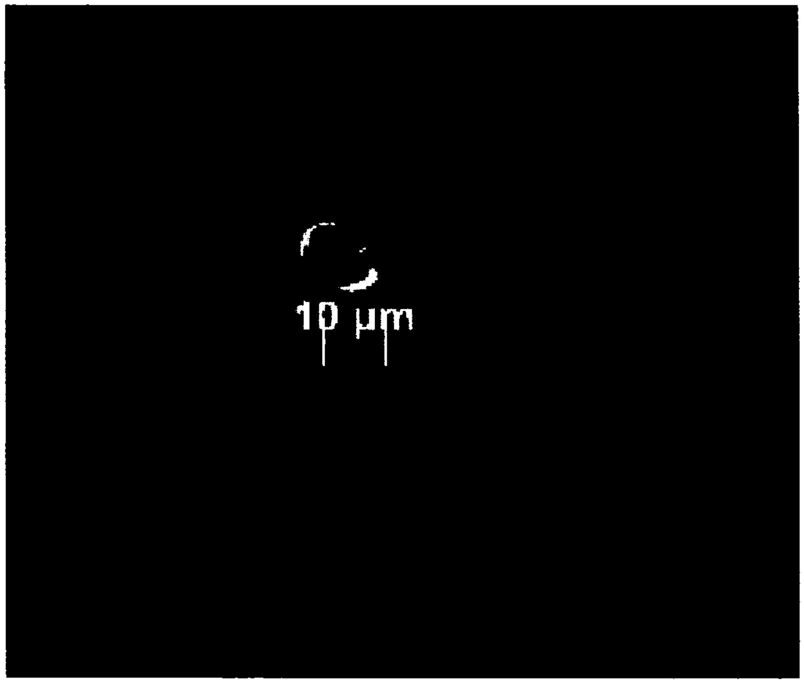

Figure 69.16: Starch Grain Consistent with cf. *Mangifera* (on rotation under polarize light)

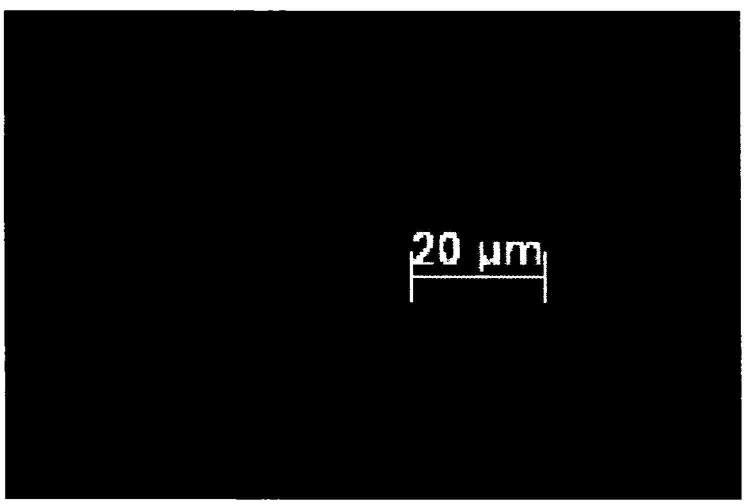

Figure 69.17: Starch from cf. Mangifera

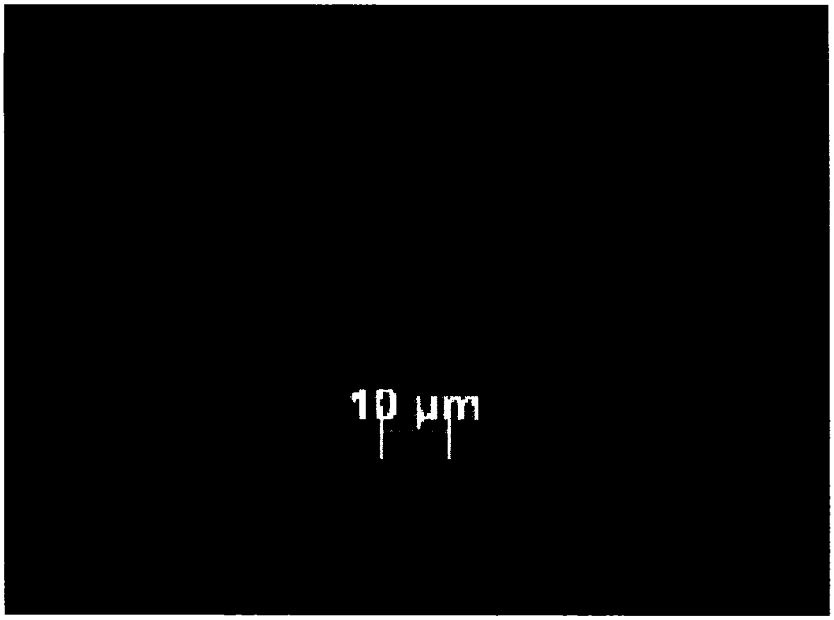

Figure 69.18: Starch Grain from cf. *Mangifera*

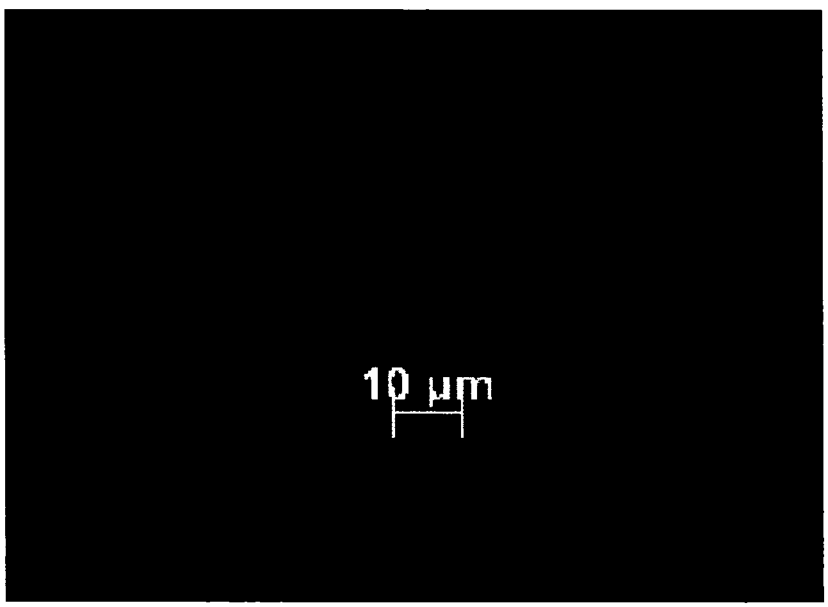

Figure 69.19: Starch Grain Consistent with cf. *Mangifera* (under polarize light)

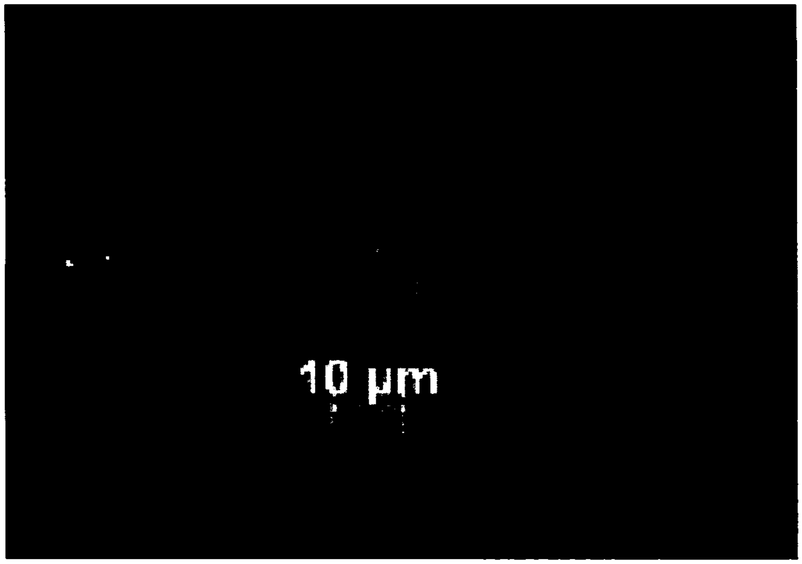

Figure 69.20: Starch Grains from cf. *Sesamum*

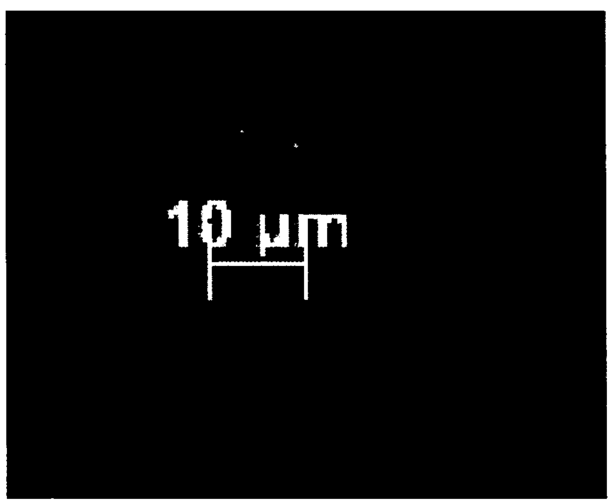

Figure 69.21: Starch Grains from cf. *Sesamum*

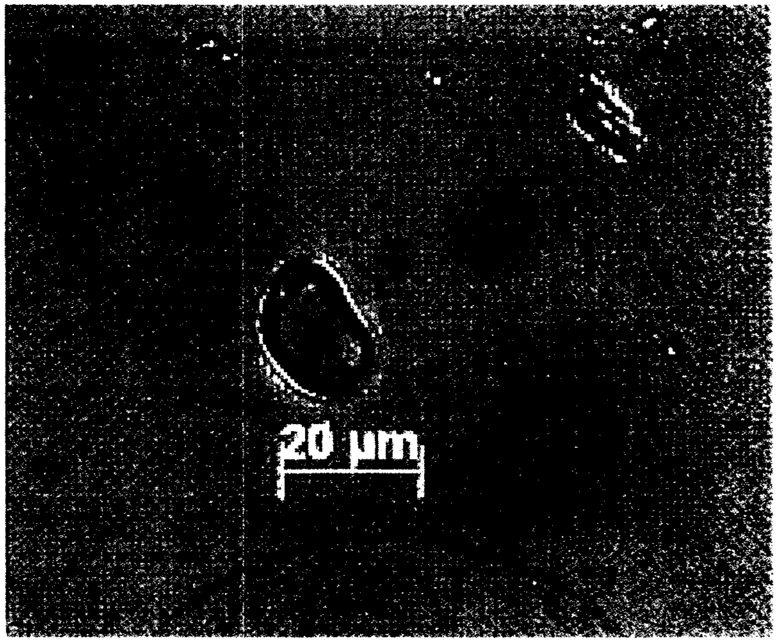

Figure 69.22: Starch Grain from cf. *Zingiber*

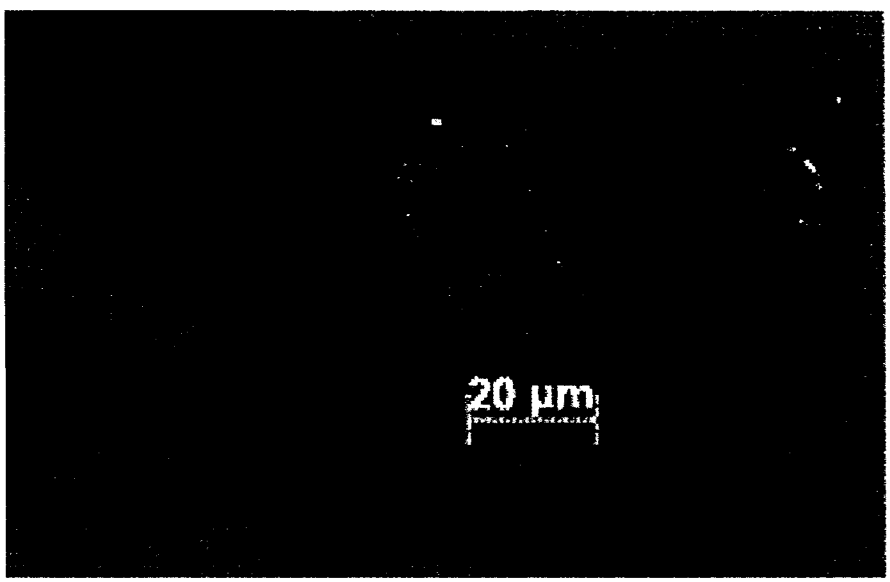

Figure 69.23: Starch Grain cf. *Zingiber* (measurement)

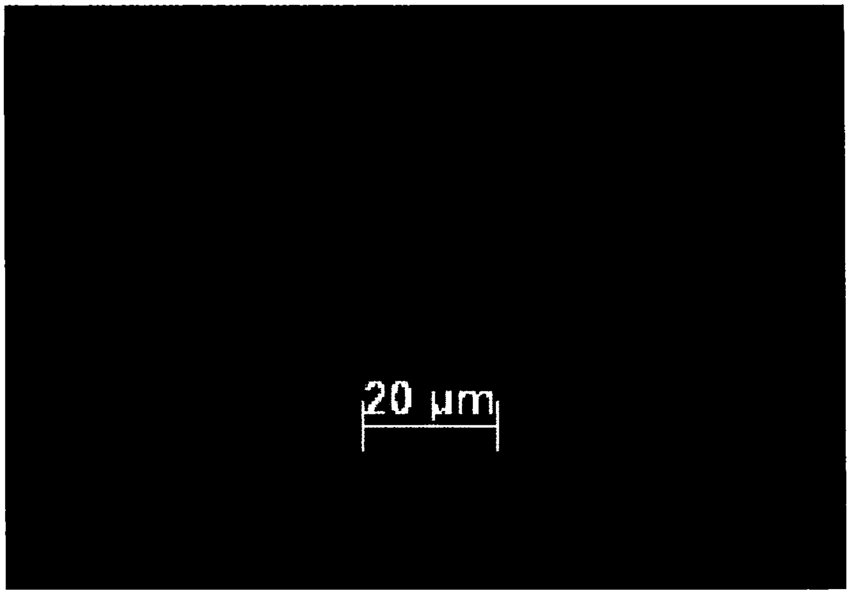

Figure 69.24: Starch Grain from cf. *Zingiber* (under polarize light)

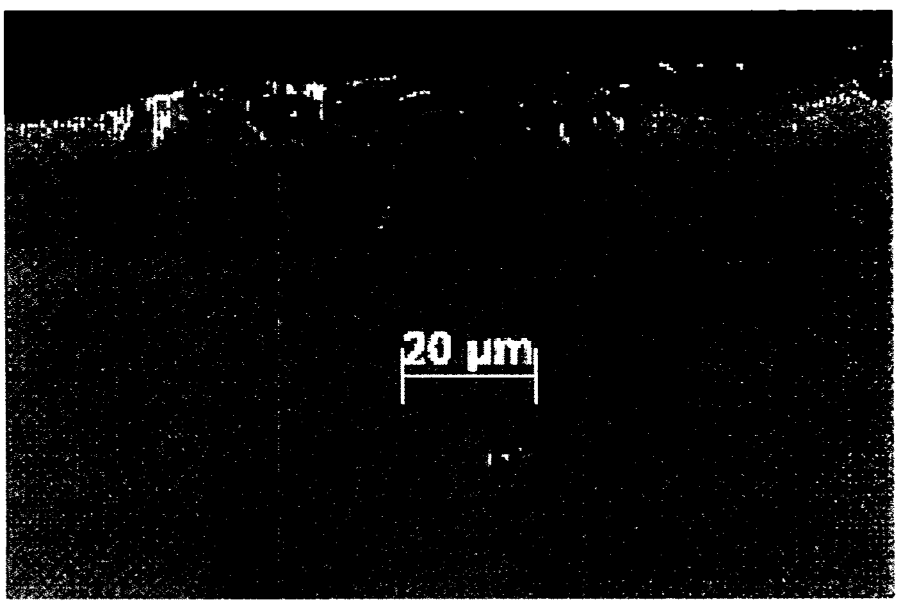

Figure 69.25: Starch Grain from Pericarp of cf. *Solanum*

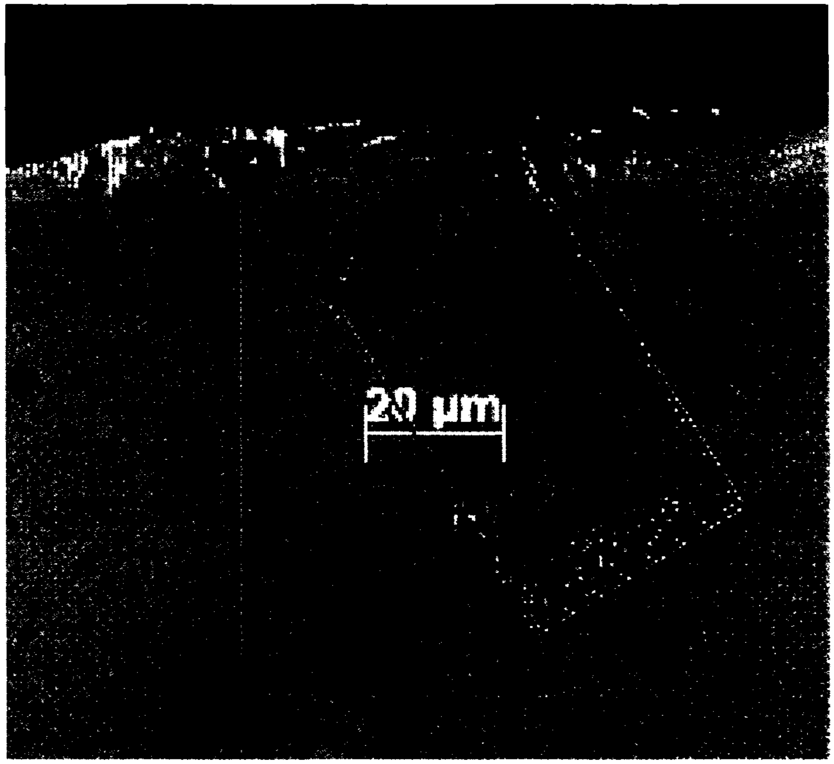

Figure 69.26: Starch Grain from Pericarp of cf. *Solanum* (measurement)

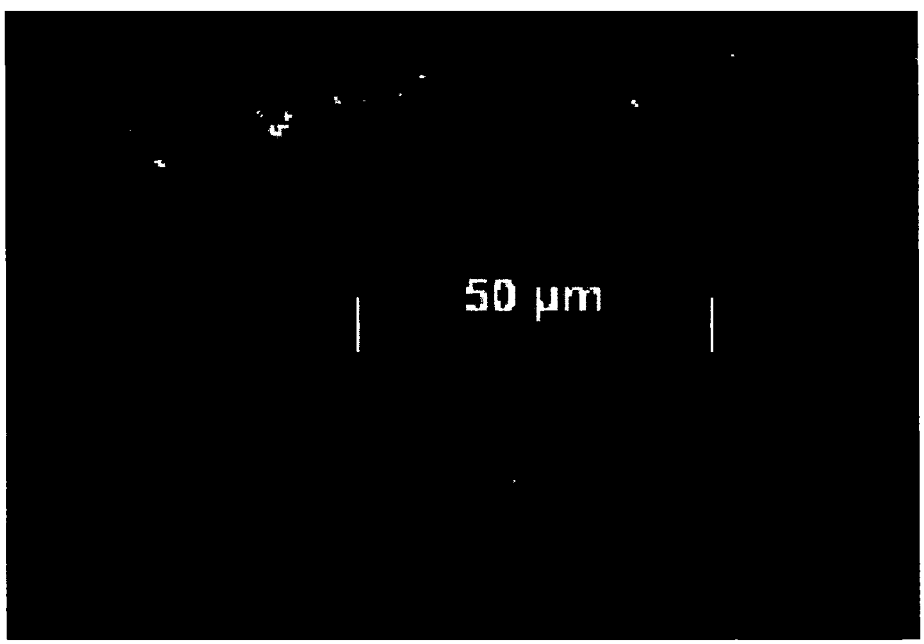

Figure 69.27: Starch Grain from Pericarp of *Solanum* (under polarize light)

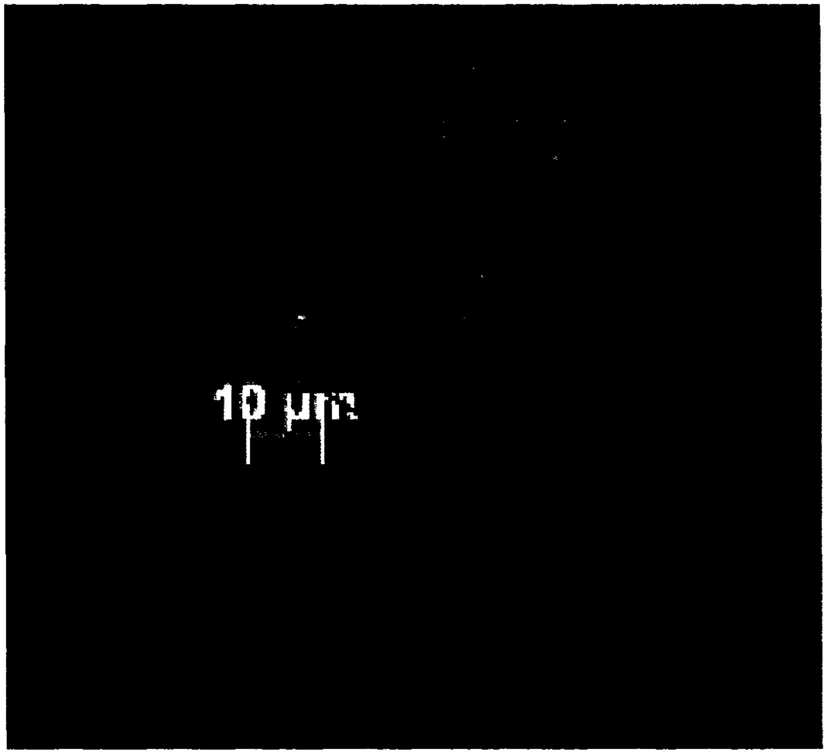

Figure 69.28: Starch Grain from cf. *Sesamum* (measurement)

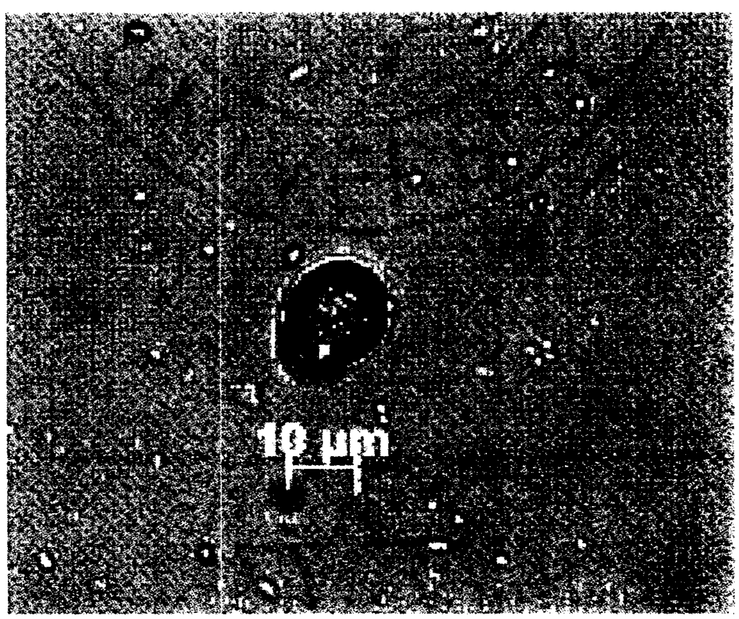

Figure 70.1: Unknown Starch

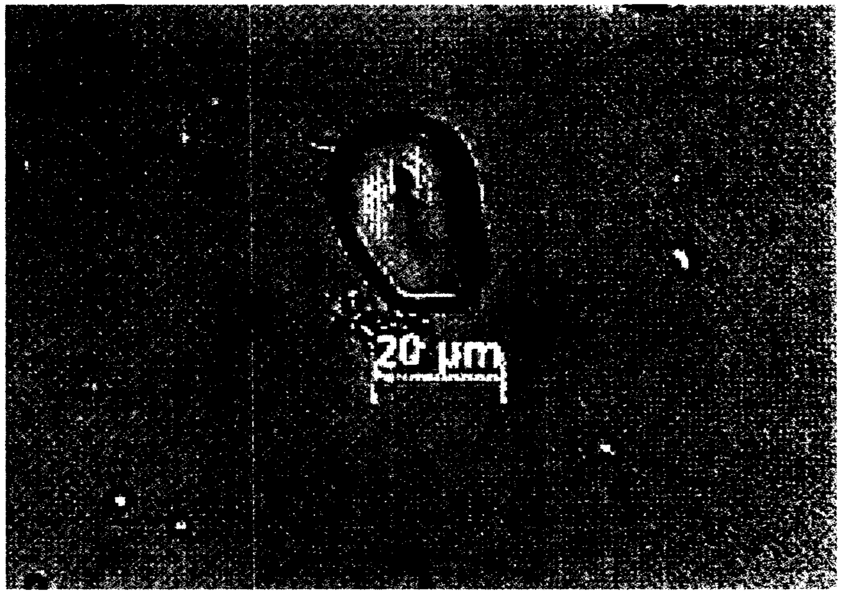

Figure 70.2: Starch from cf. *Zingiber*

Figure 70.3: Starch from cf. *Zingiber*

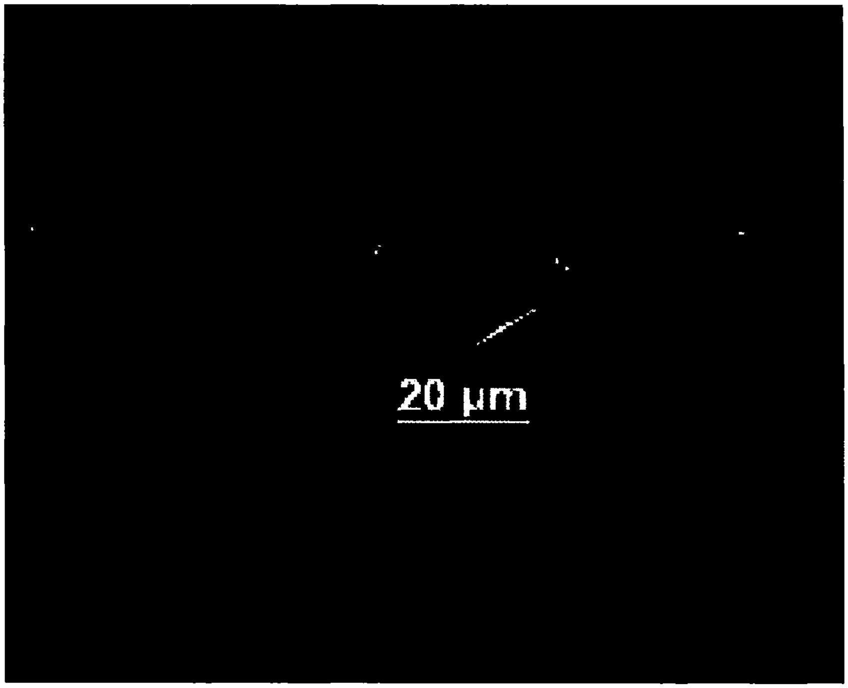

Figure 70.4: Starch from cf. *Zingiber* (under polarize light)

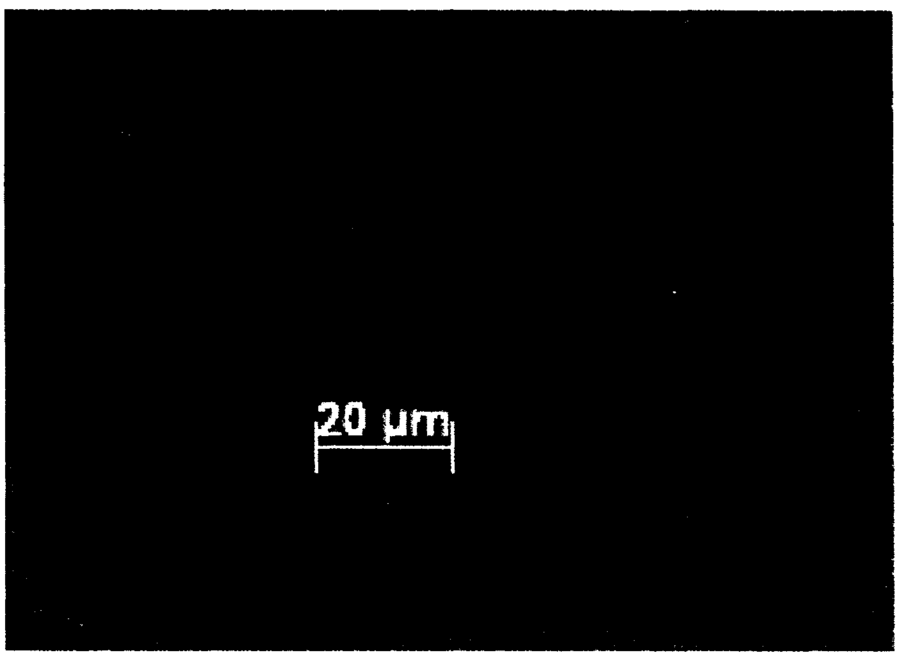

Figure 70.5: Starch from cf. *Zingiber*

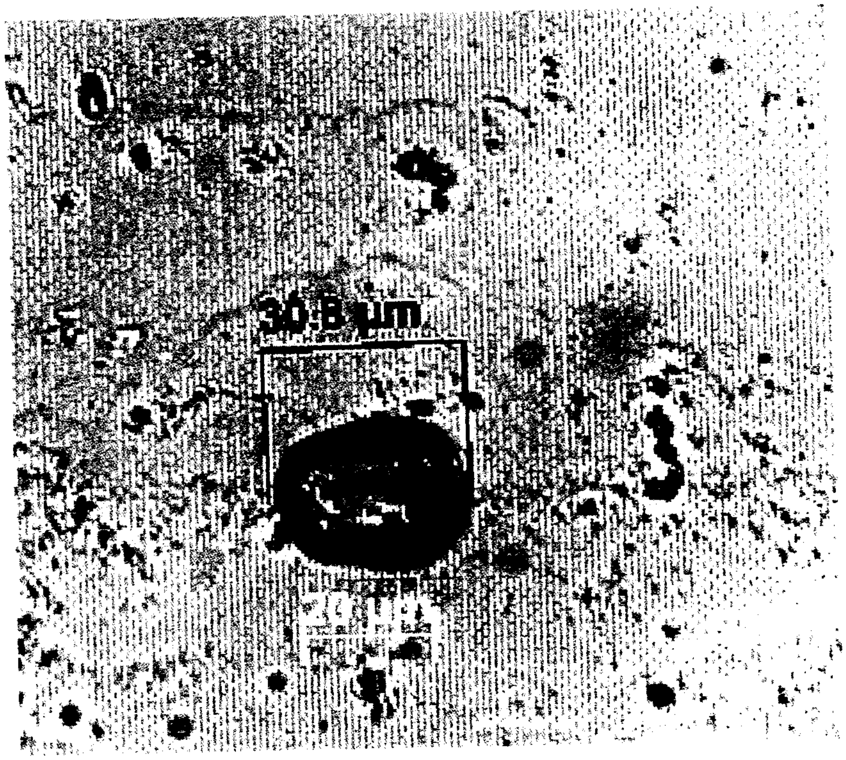

Figure 70.6: Starch from cf. *Zingiber* (measurement)

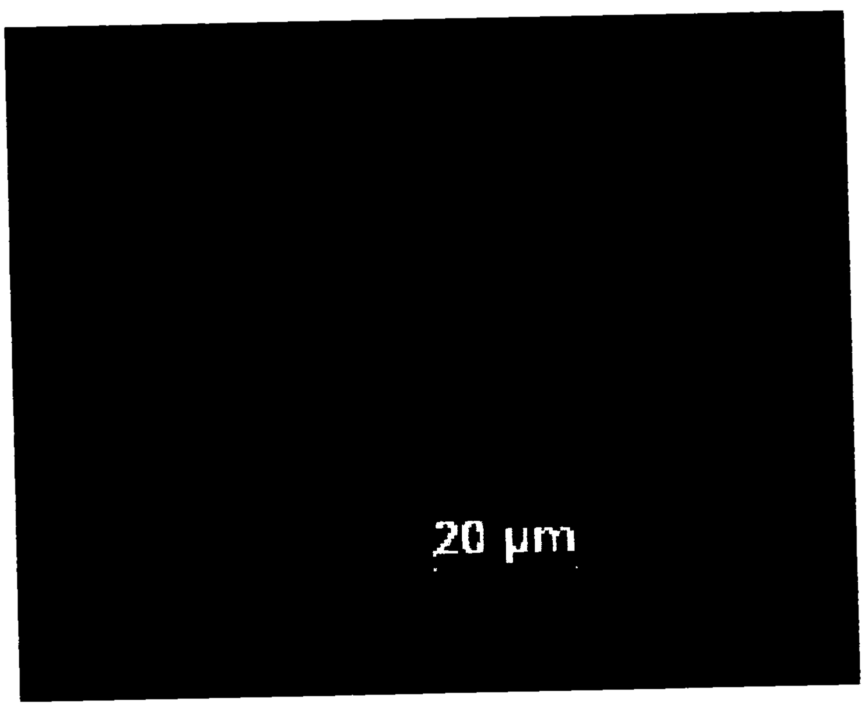

Figure 70.7: Starch from cf. *Zingiber* (under polarize light)

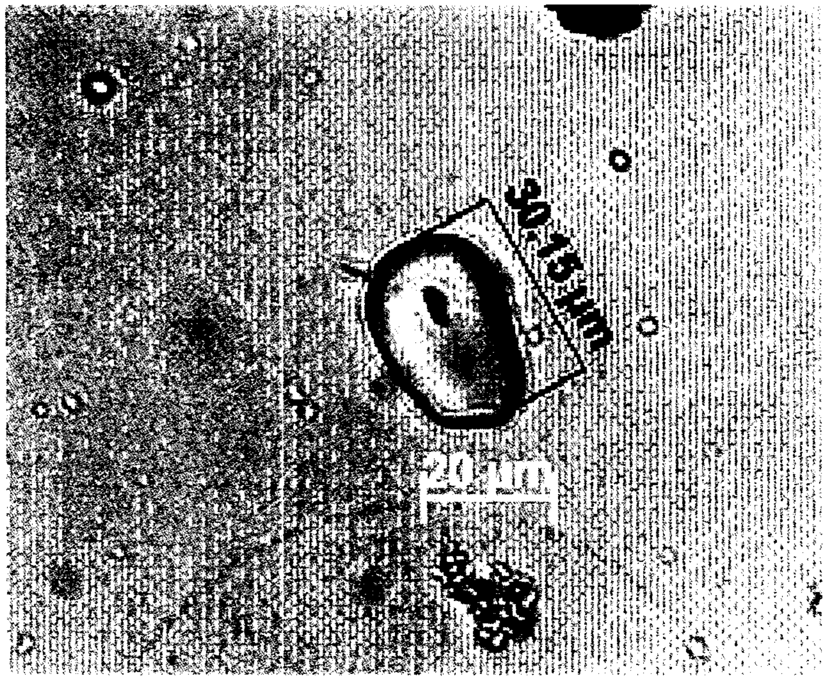

Figure 70.8: Starch from cf. *Zingiber* (measurement)

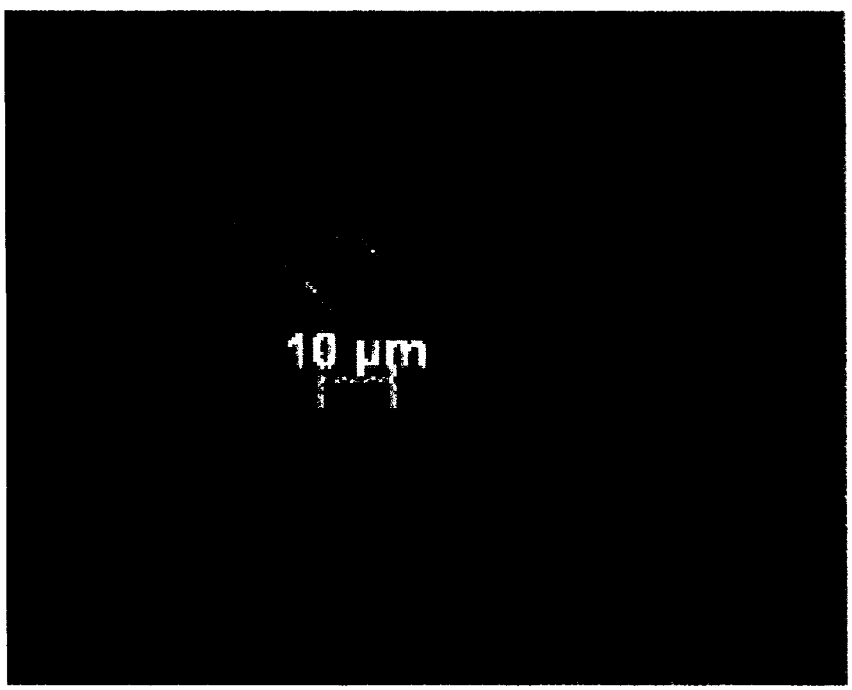

Figure 70.9 Unknown Starch 1

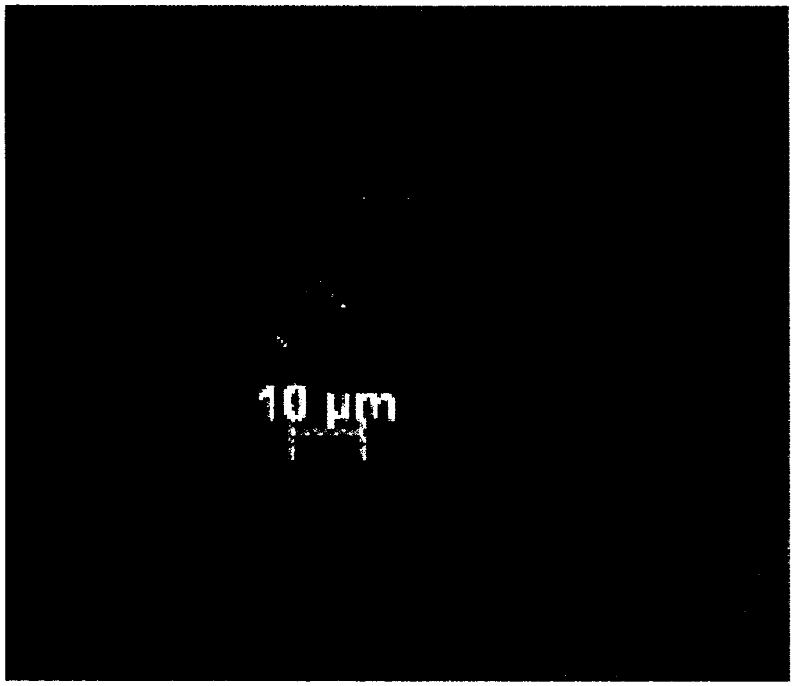

Figure 70.10: Unknown Starch (measurement)

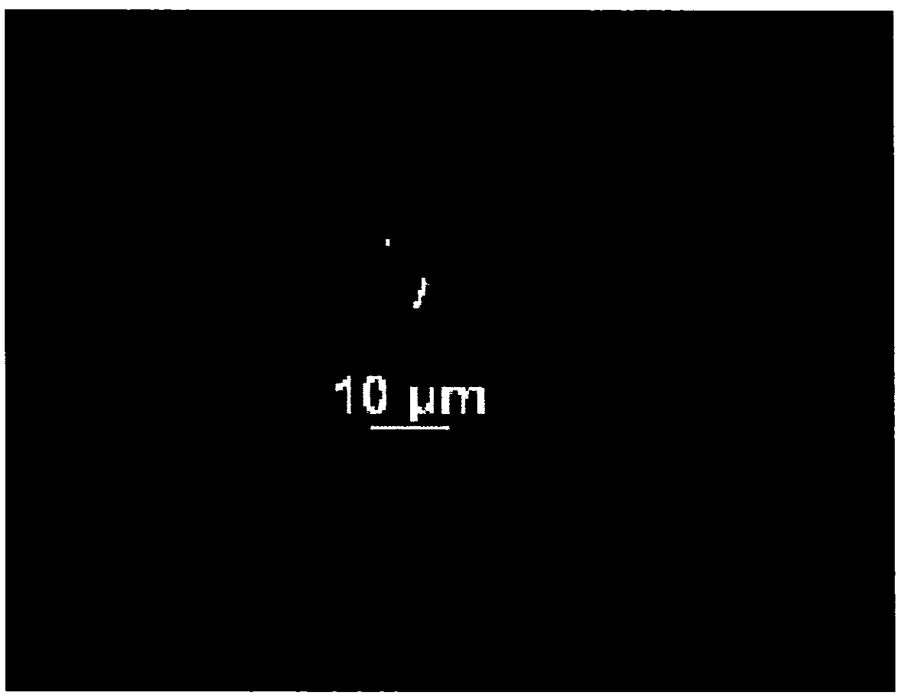

Figure 70.11: Unknown Starch under (polarize light)

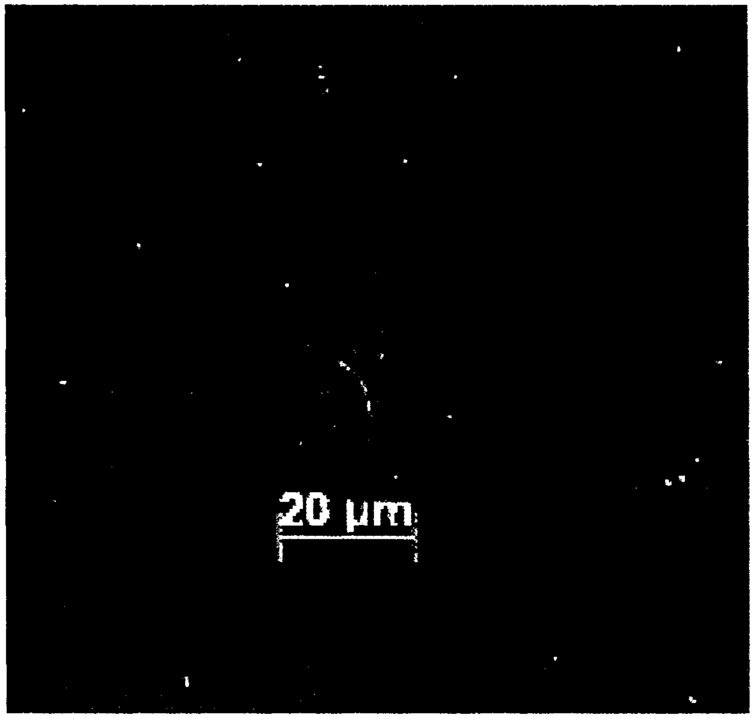

Figure 70.12: Elongate Starch from cf. *Phoenix*

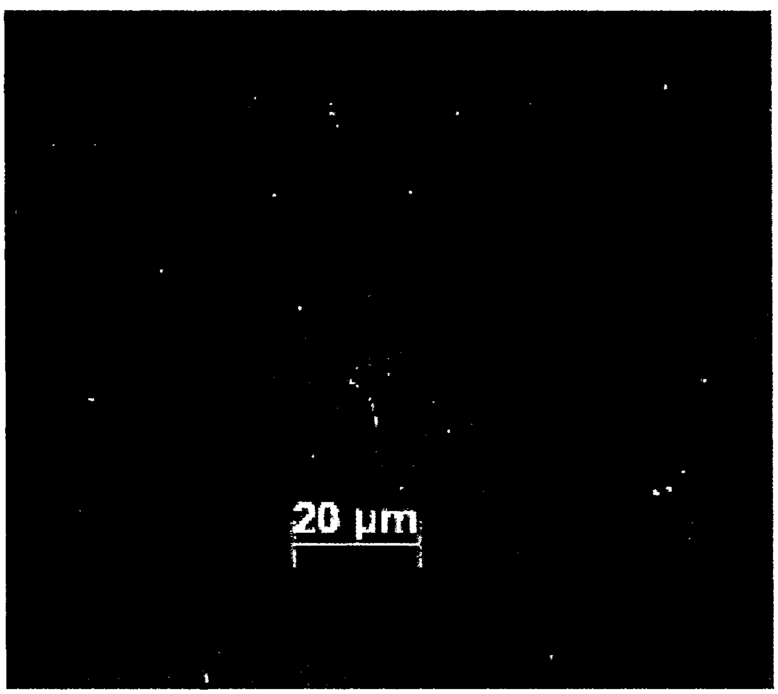

Figure 70.13: Elongate Starch from cf. *Phoenix* (measurement)

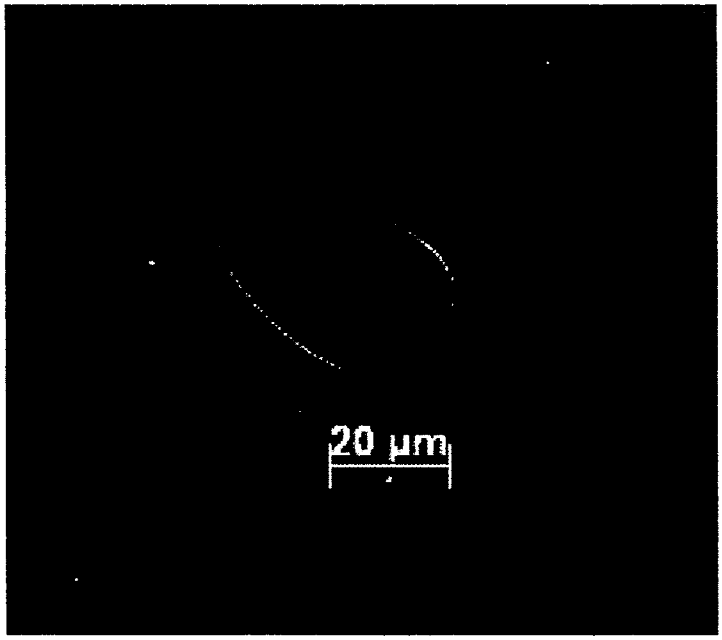

Figure 70.14: Starch from cf. *Zingiber*

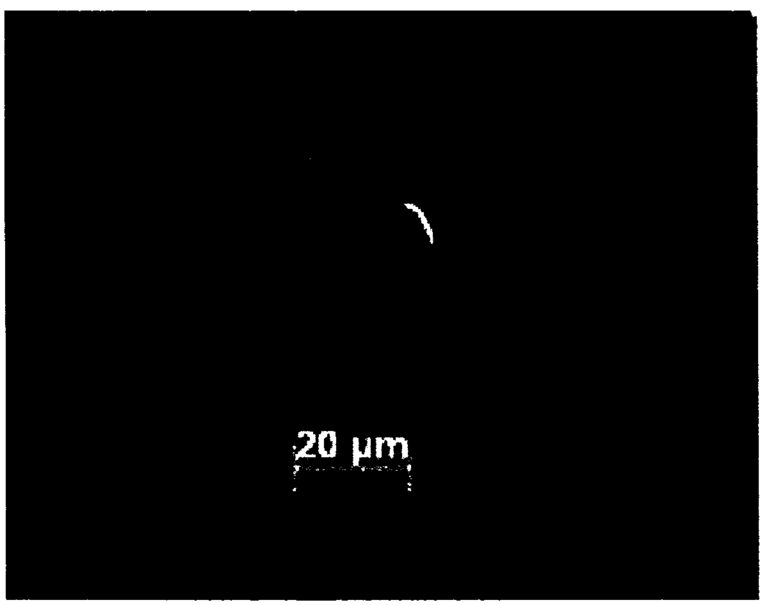

Figure 70.15: Starch from cf. *Zingiber* (measurement)

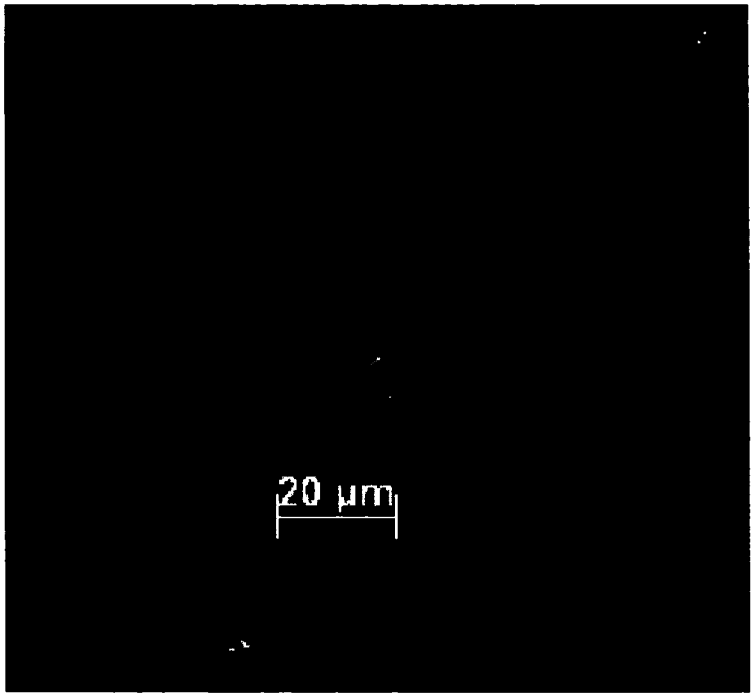

Figure 70.16: Starch from cf. *Zingiber* (under polarize light)

APPENDIX H

SAMPLES STUDIED FROM CERAMIC MESOLITHIC FOR STARCH GRAIN ANALYSIS

This appendix provides the context of the Samples studied for Starch grain Analysis for the ceramic Mesolithic phase. It also provides the photographs of the starches found in each of the samples studied. (All pictures are 20 μm unless mentioned otherwise)

Sample Number	Sample Studied	Trench Number	Lot Number	Depth	Locus
Sample 2 (Retouched Blade) **(Figures 71.1 - 71.11)**	Tool Wash + Tool Sonic	1A	1005	-35cm	All
Sample 3 (Flake) **(Figures 72.1-72.12)**	Tool Wash + Tool Sonic	1C	3005	-43cm	South Half
Sample 5 (Crescent) **(Figures 73.1 - 73.7 and 74.1-74.6)**	Tool Wash + Tool Sonic	1A	1006	-35cm	All
Sample 8 (Retouched Blade) **(Figures 75.1 -75.5 and 76.1- 76.10)**	Tool Wash + Tool Sonic	1C	3003	-38cm	All
Sample 12 (Crescent) **(Figures 77.1 - 77.10 and 78.1-78.6)**	Tool Wash + Tool Sonic	1E	5005	-41cm	All
Sample 14 (Retouched Blade) **(Figures 79.1 – 79.5 and 80.1- 80.22)**	Tool Wash + Tool Sonic	1D	4002	-32cm	North Half

APPENDIX H

Sample Number	Sample Studied	Trench Number	Lot Number	Depth	Locus
Sample 15 (Retouched Blade) **(Figures 81.1 - 81.5, 82.1, 83.1 -83.15, 84.1 - 84.5)**	Tool Wash + Tool Sonic + Too Brush + Soil Around the Tool	1A	1003	-24cm	South Half
Sample 17 (Unretouched Blade) **(Figure 85.1 – 85.6)**	Tool Sonic	1B	2006	-40cm	North Half
Sample 22 **(Figure 86.1 – 86.21)**	Soil Sample	1A	1005	-35cm	All
Sample 26 **(Figures 87.1 – 87.7)**	Soil Sample	1E	5005	-41cm	All
Sample 25 **(Figures 88.1 – 87. 43)**	Grinder	1E	2019	-42cm	South Half

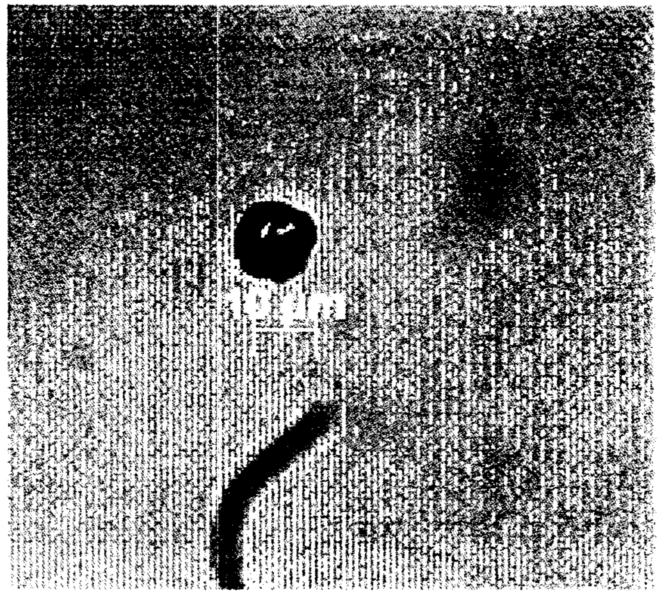

Figure 71.1: Unknown Damaged Starch 1

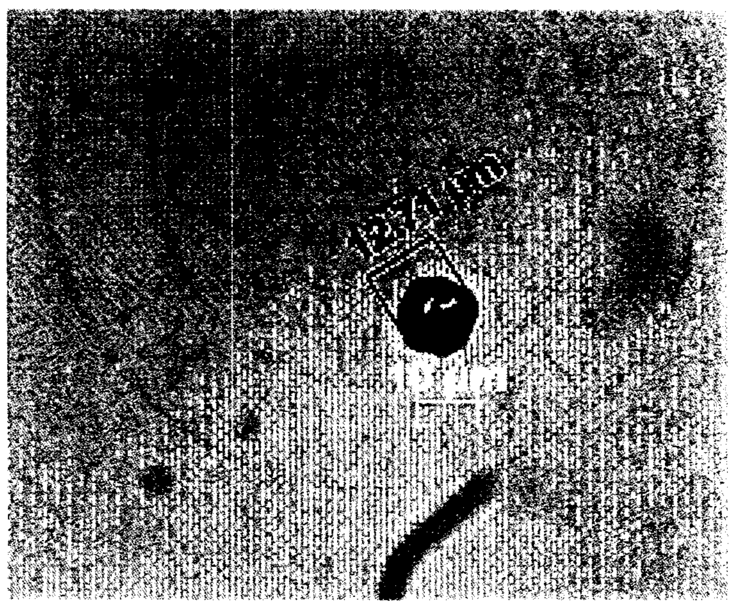

Figure 71.2: Unknown Damaged Starch 1 (measurement)

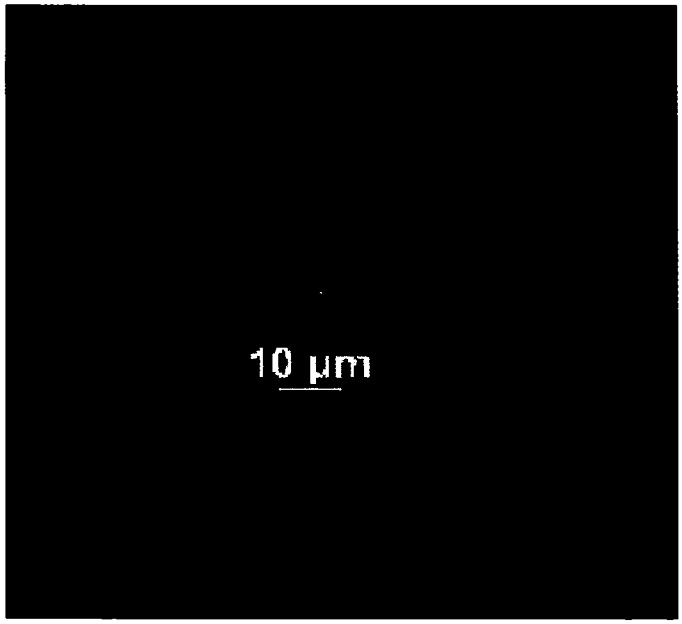

Figure 71.3: Unknown Damaged Starch 1 (under polarize light)

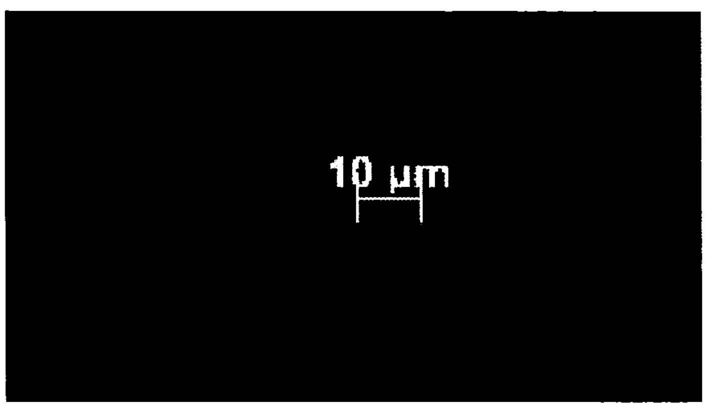

Figure 71.4: Spherical Starch from cf. *Tamarindus*

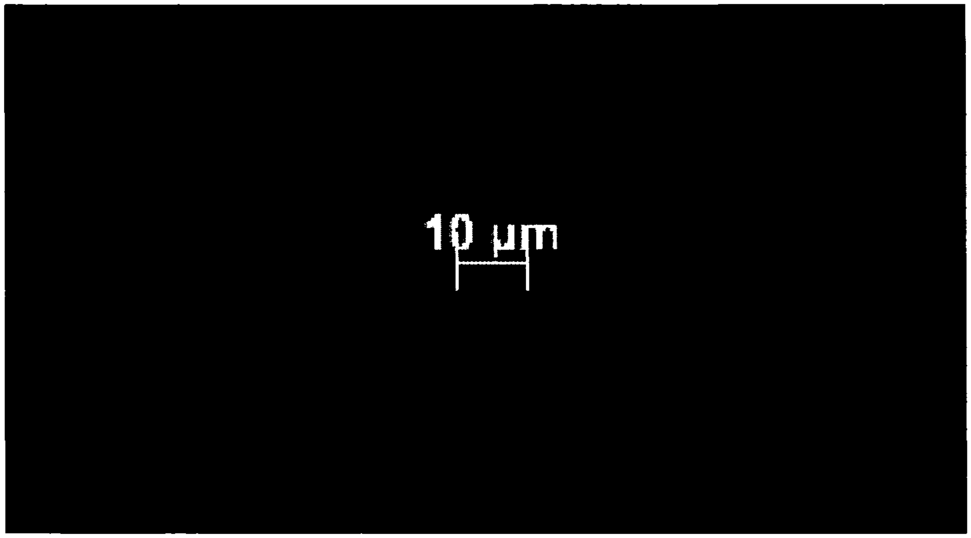

Figure 71.5: Spherical Starch from cf. *Tamarindus* (measurement)

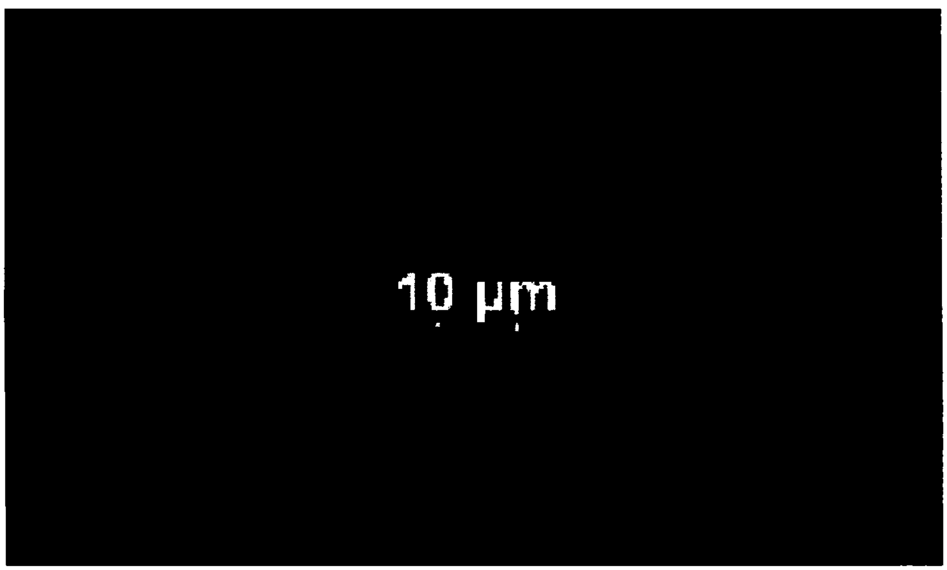

Figure 71.6: Spherical Starch from cf. *Tamarindus* (under polarize light)

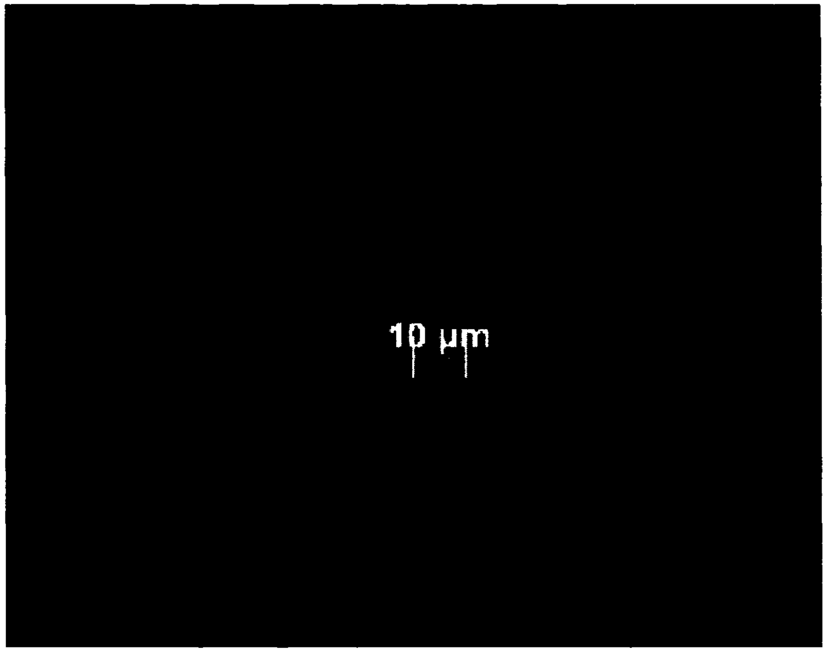

Figure 71.7: Compound Starch

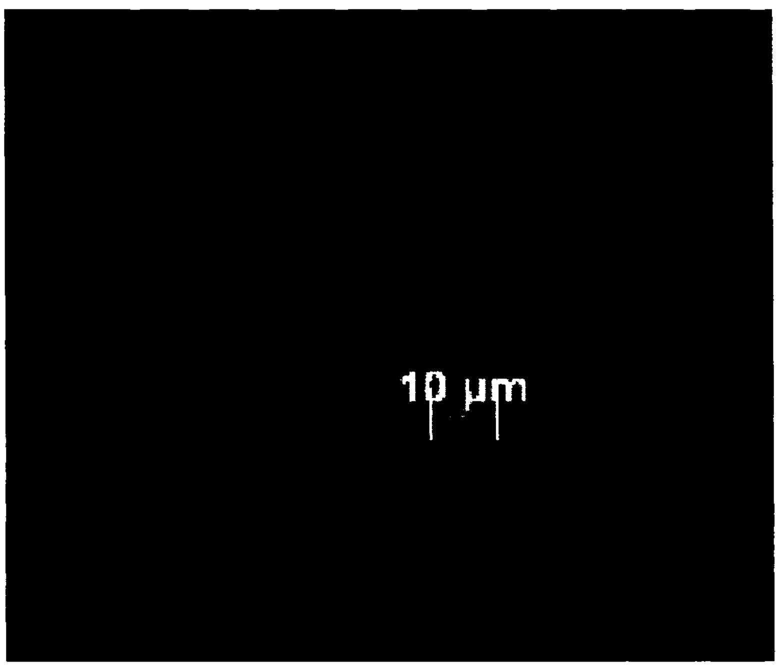

Figure 71.8: Compound Starch (measurement)

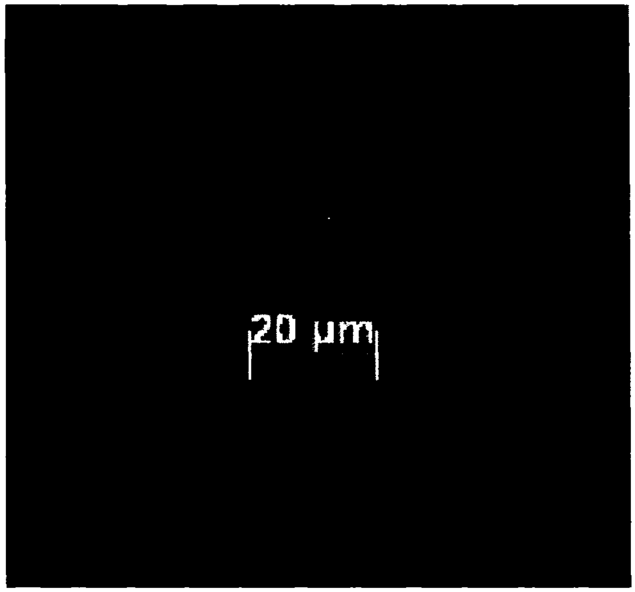

Figure 71.9: Damaged Starch from Pericarp of cf. *Solanum*

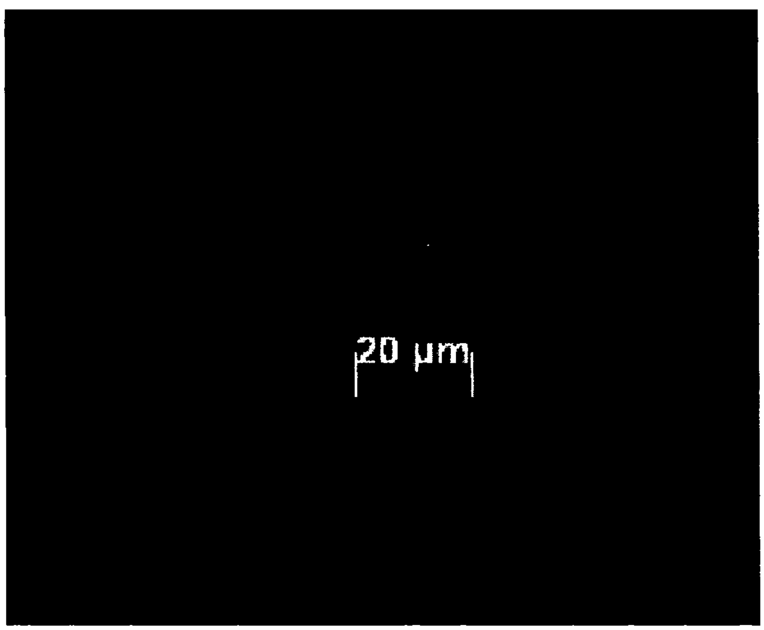

Figure 71.10: Damaged Starch from Pericarp of cf. *Solanum* (measurement)

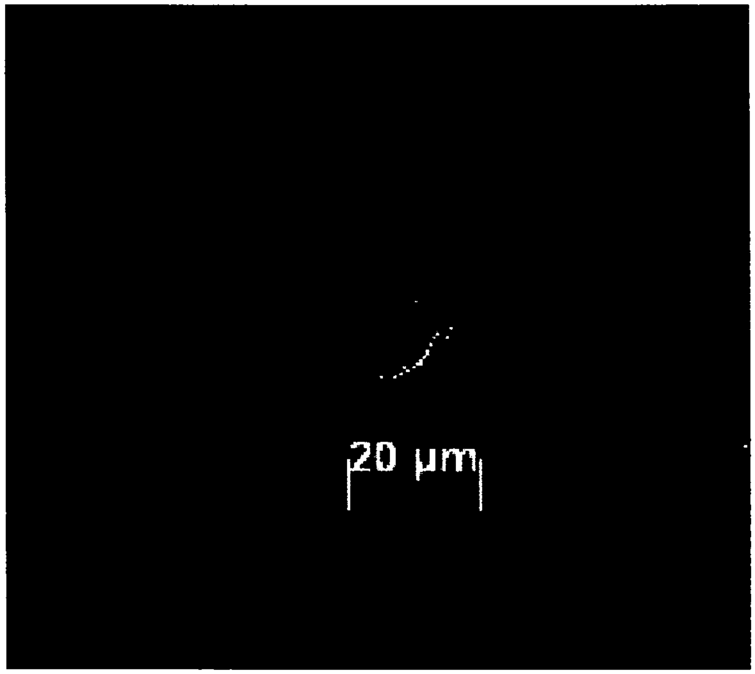

Figure 71.11: Damaged Starch from Pericarp of cf. *Solanum* (under polarize light)

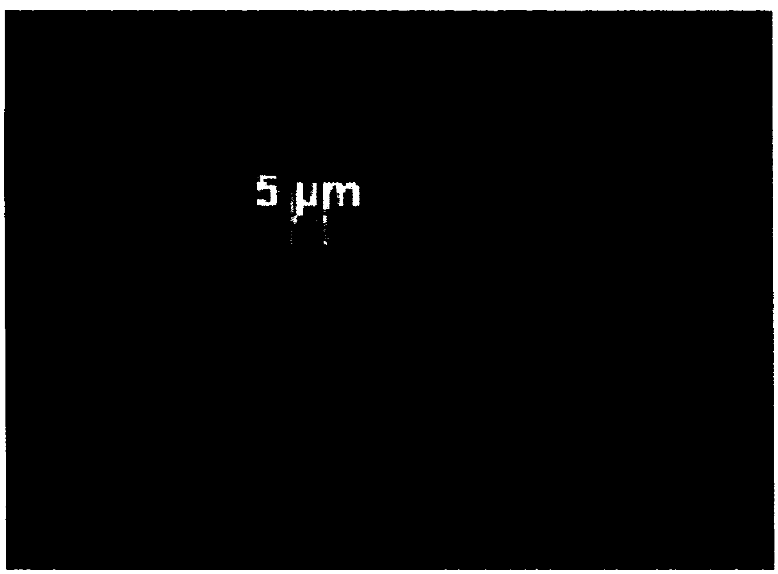

Figure 72.1: Compound Starch

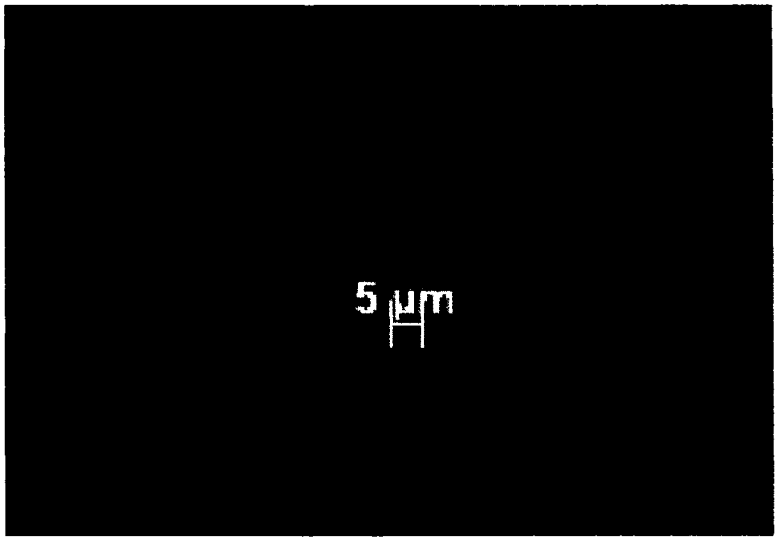

Figure 72.2: Compound Starch (measurement)

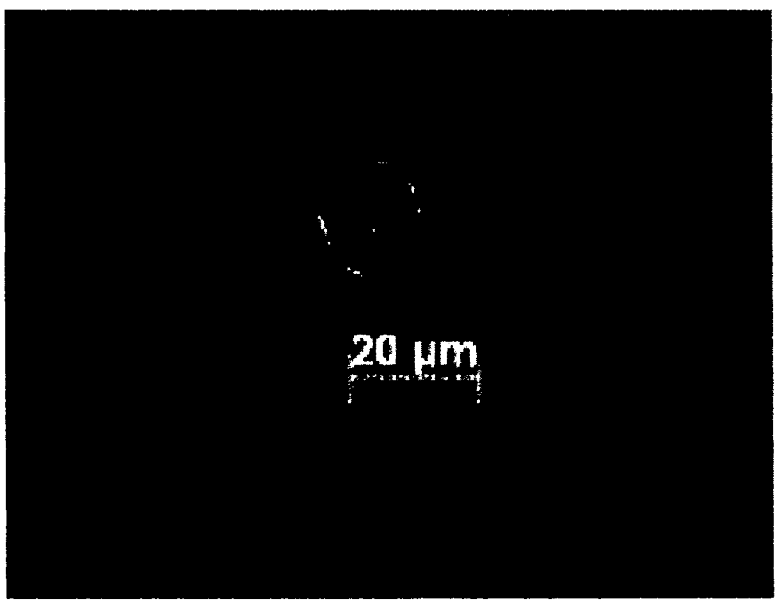

Figure 72.3: Damaged Starch 1

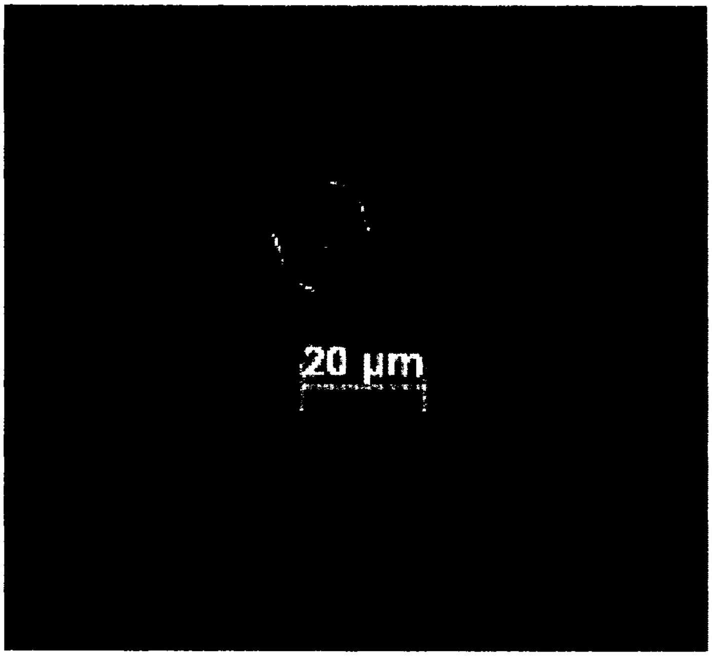

Figure 72.4: Damaged Starch 1 (measurement)

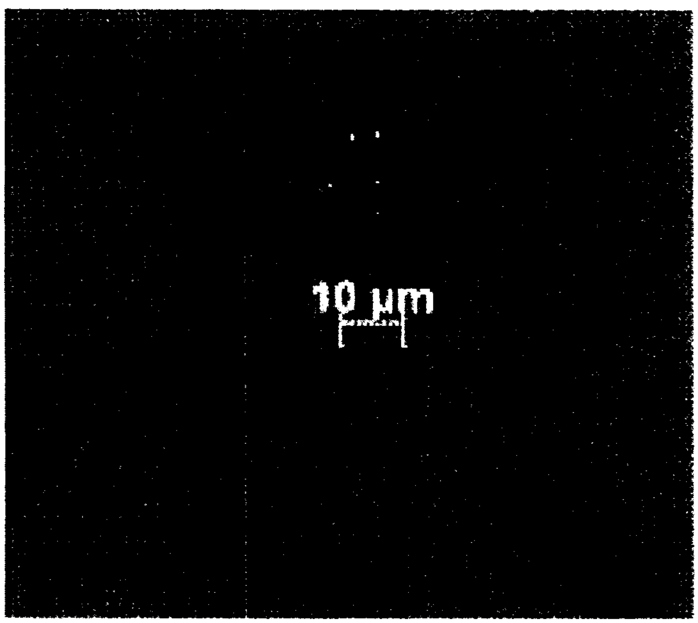

Figure 72.5: Compound Starch Cluster

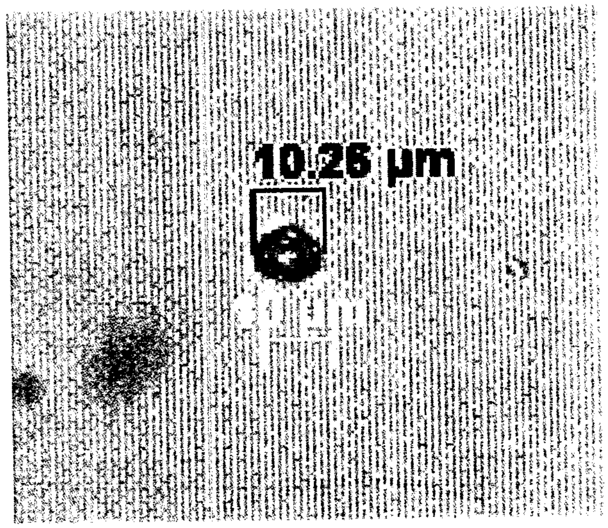

Figure 72.6: Compound Starch (measurement)

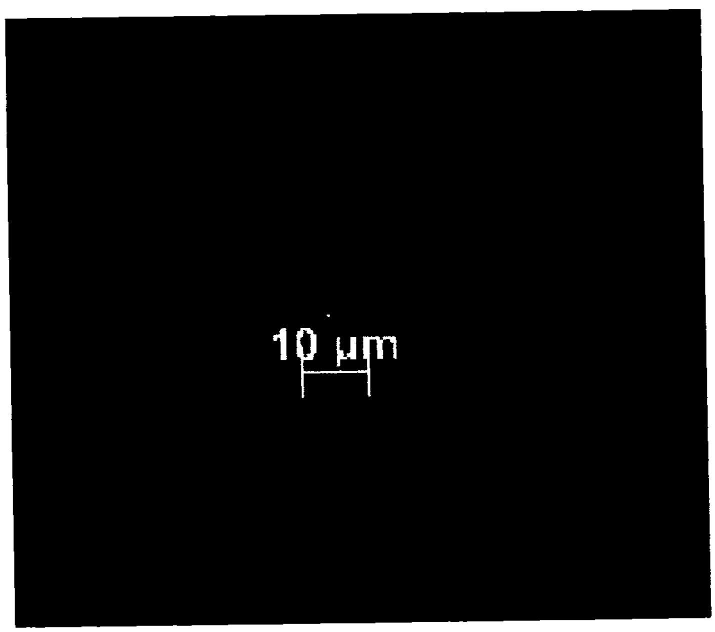

Figure 72.7: Compound Starch (under polarize light)

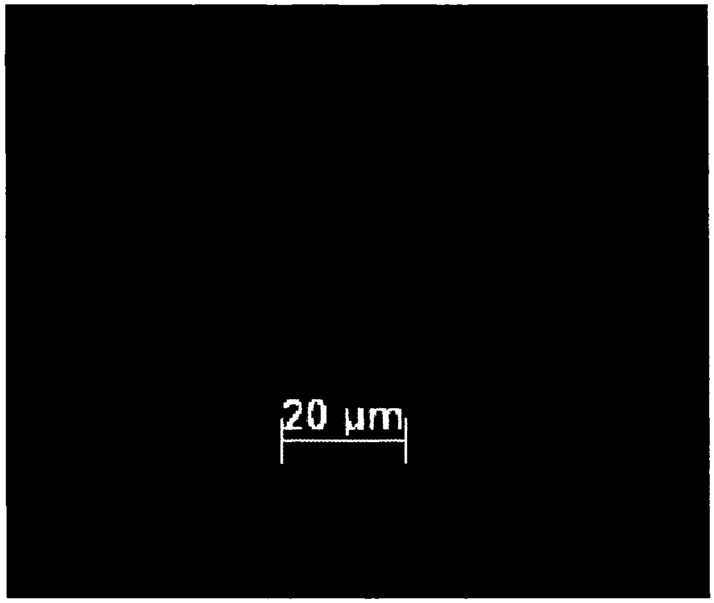

Figure 72.8: Damaged Starch 2

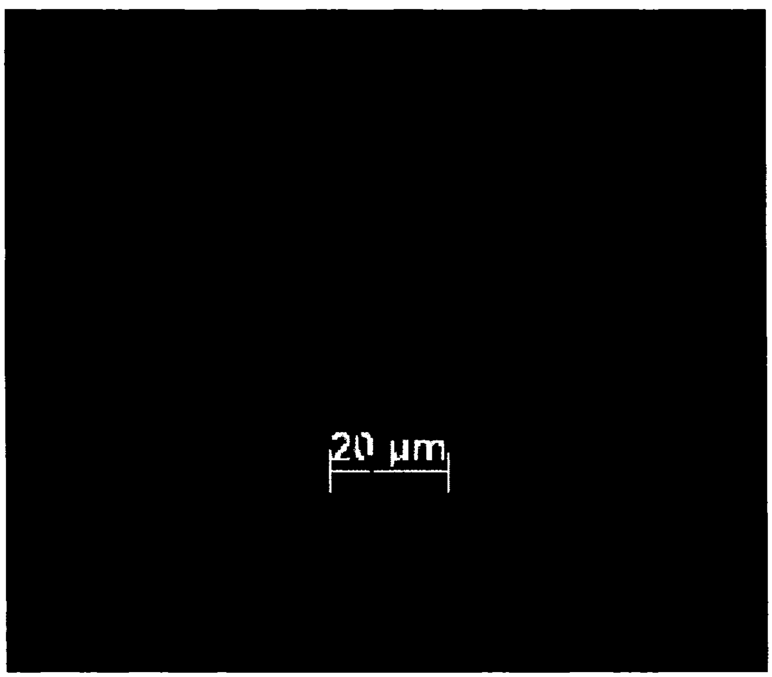

Figure 72.9: Damaged Starch 2 (measurement)

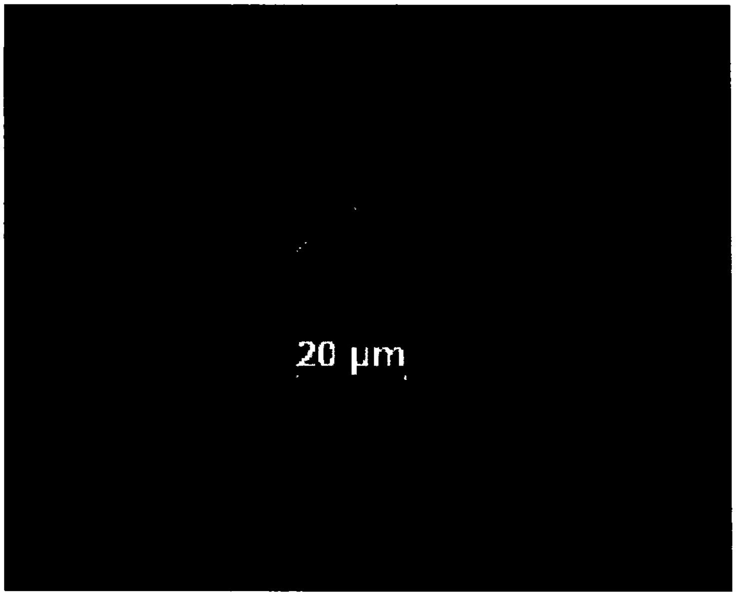

Figure 72.10: Damaged Starch 2 (under polarize light)

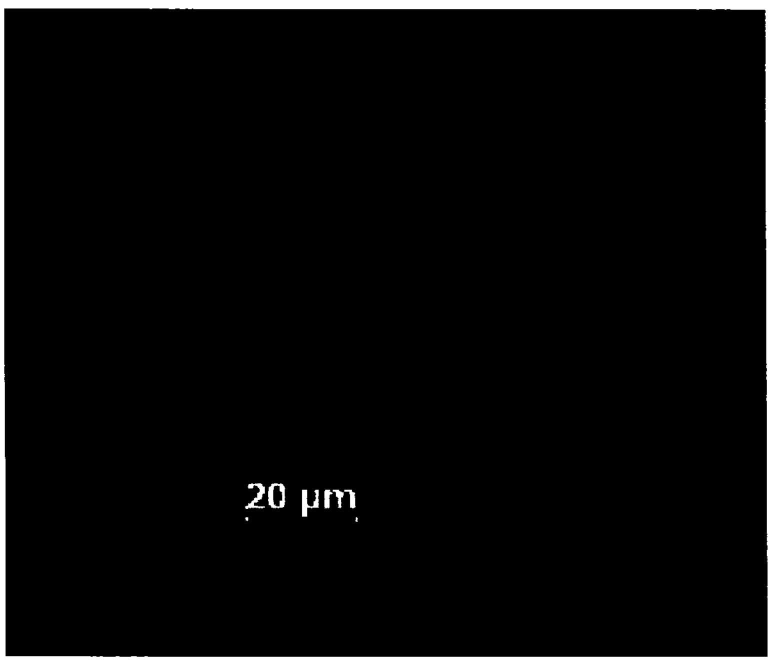

Figure 72.11: Unknown Starch

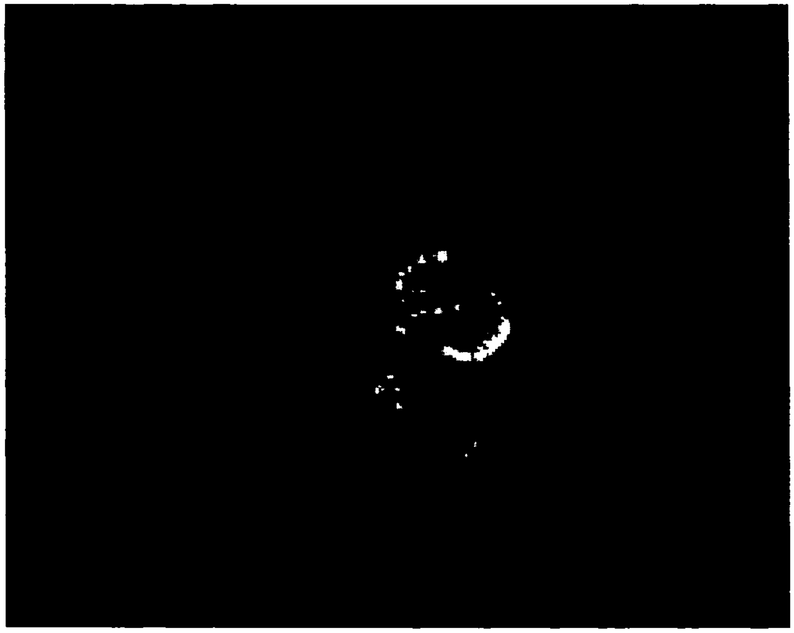

Figure 72.12: Unknown Starch (under polarize light)

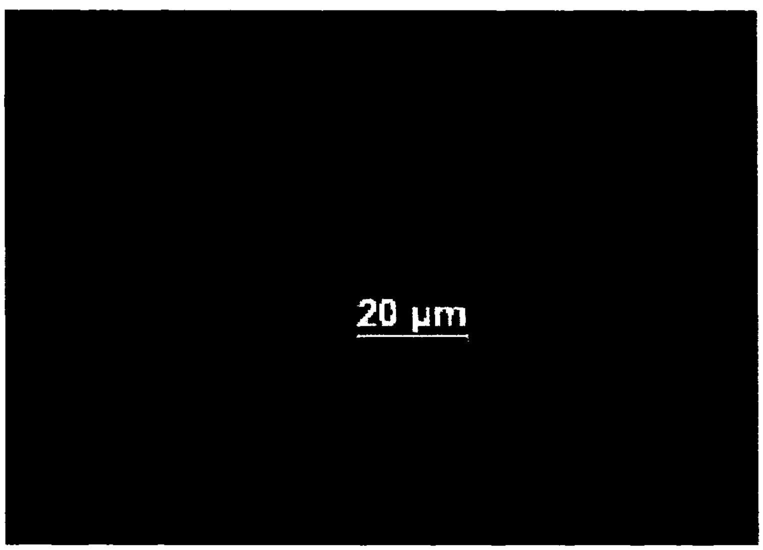

Figure 73.1: Elongate Starch from Pericarp of cf. *Solanum* (characteristic double edges)

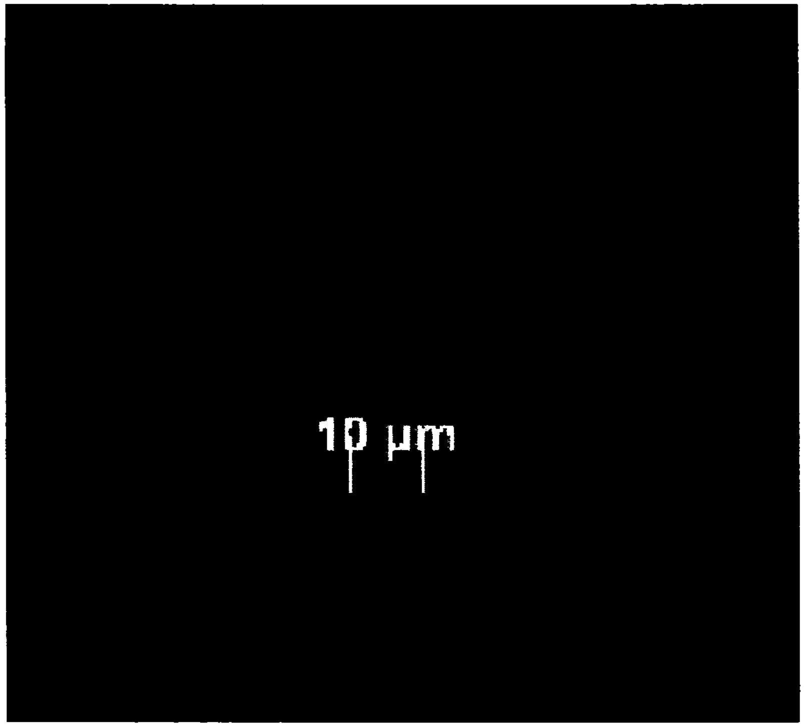

Figure 73.2: Elongate Starch from Pericarp of cf. *Solanum* (on rotation)

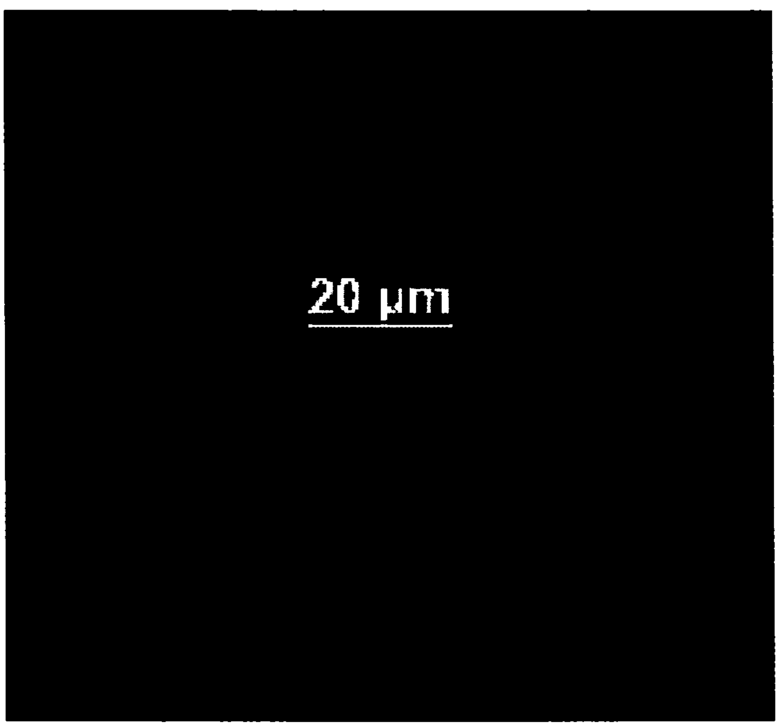

Figure 73.3: Elongate Starch from Pericarp of cf. *Solanum* (under polarize light)

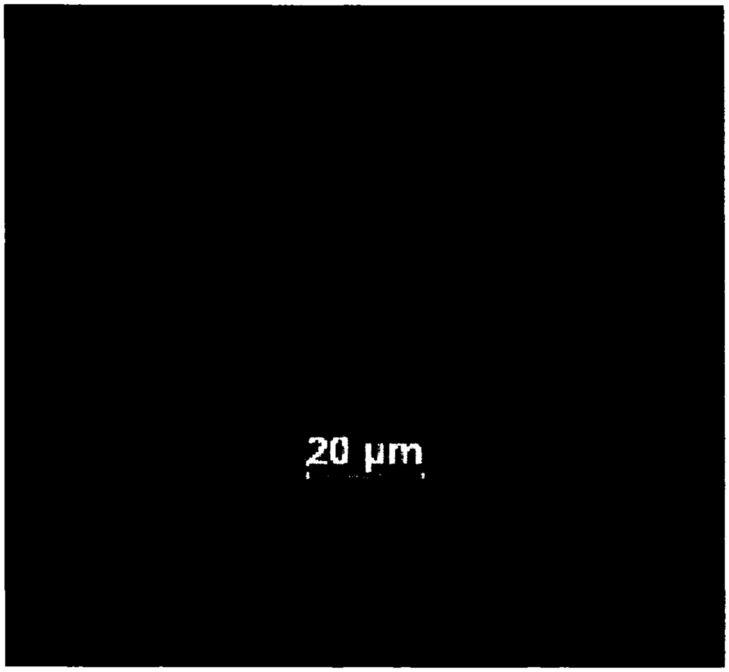

Figure 73.4: Elongate Starch from Pericarp of cf. *Solanum* (under polarize light)

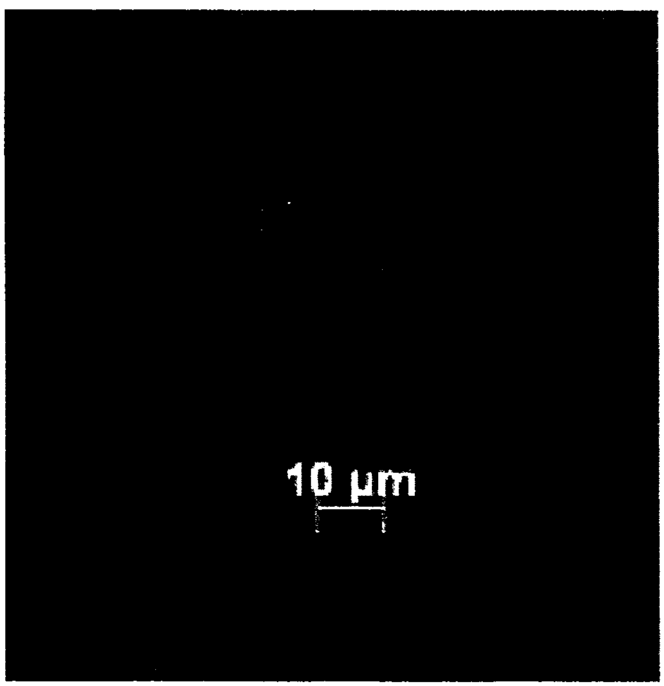

Figure 73.5: Elongate Starch from Pericarp of cf. *Solanum* (measurement)

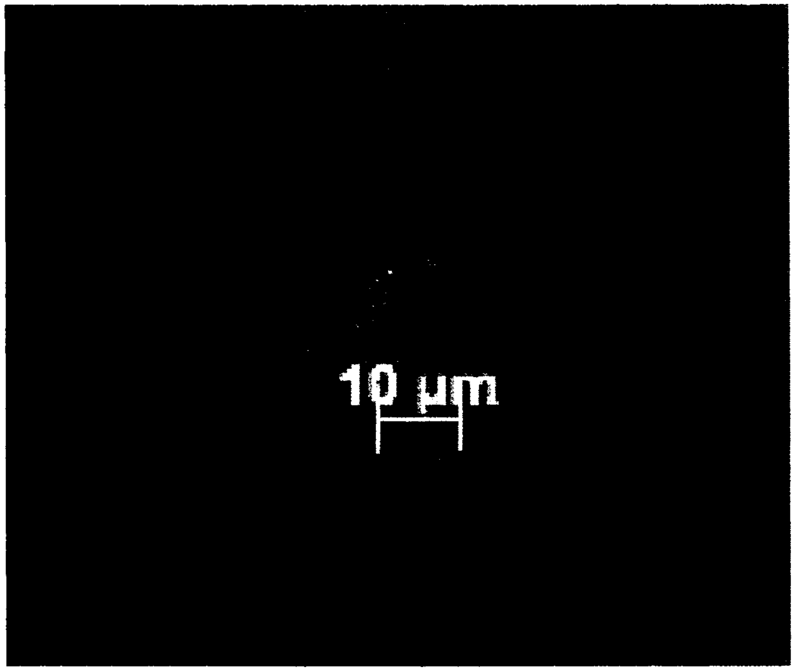

Figure 73.6: Elongate Starch from Pericarp of cf. *Solanum* (on rotation)

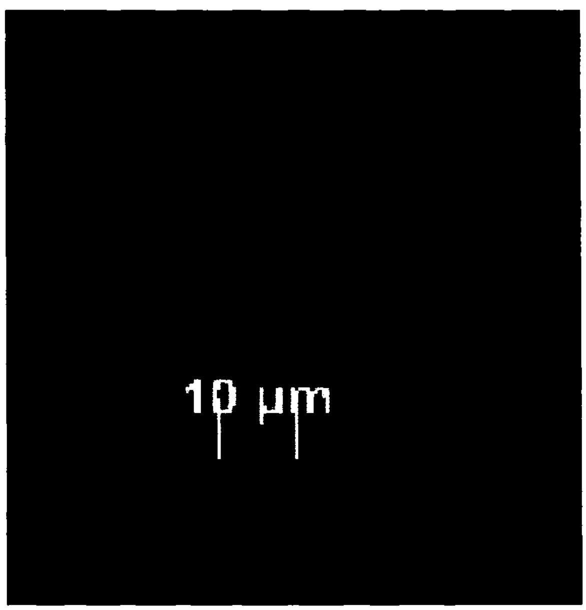

Figure 73.7: Elongate Starch from Pericarp of cf. *Solanum* (under polarize light)

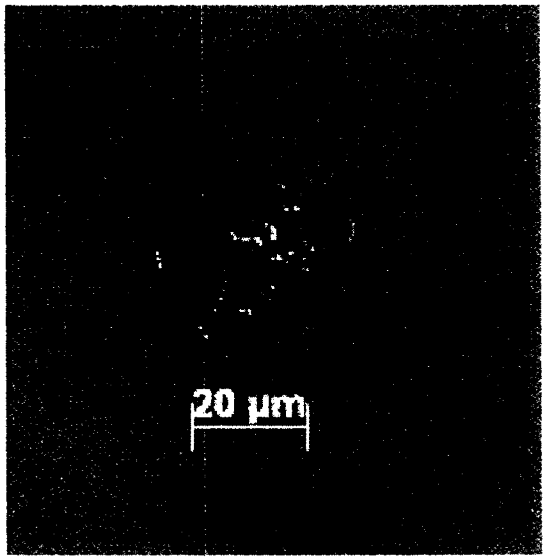

Figure 74.1: Damaged Starch from Unknown Bean

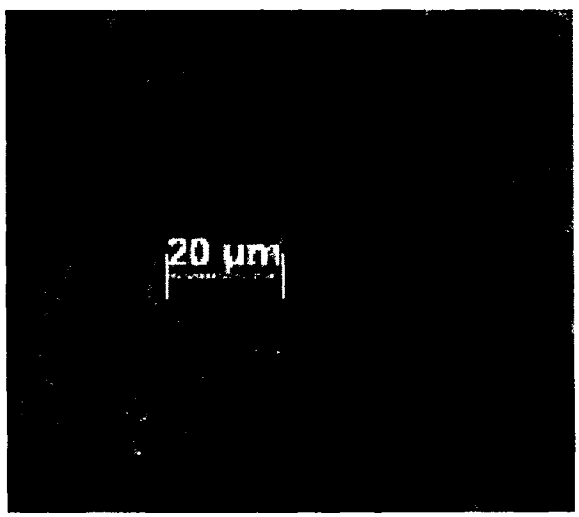

Figure 74.2: Elongate Starch from cf. *Solanum*

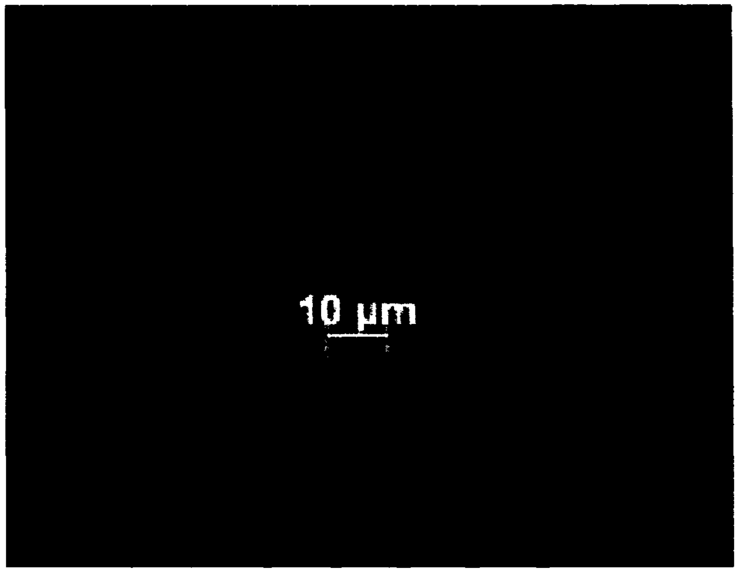

Figure 74.3: Compound Starch

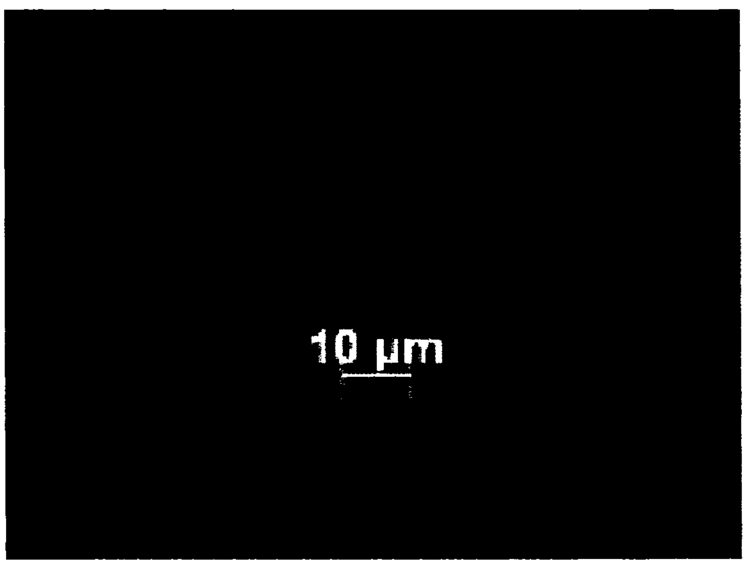

Figure 74.4: Compound Starch (measurement)

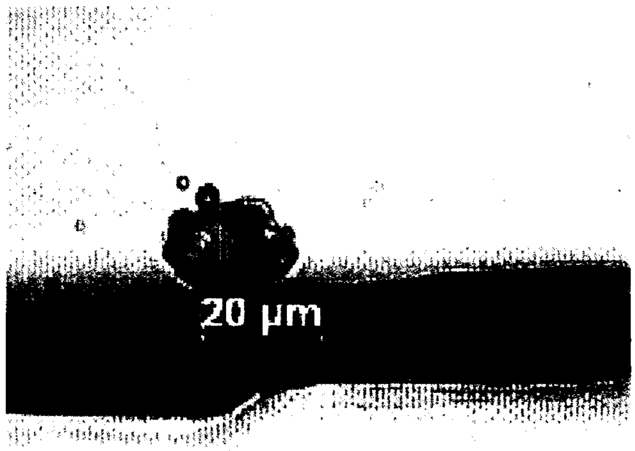

Figure 74.5: Elongate Starch from cf. *Solanum*

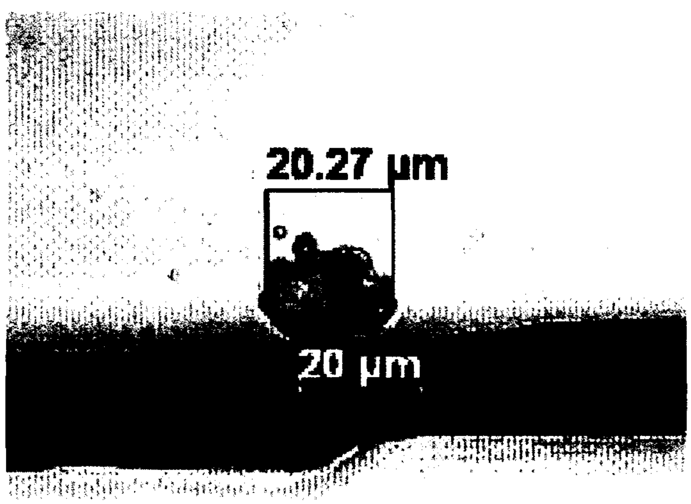

Figure 74.6: Elongate Starch from cf. *Solanum* (measurement)

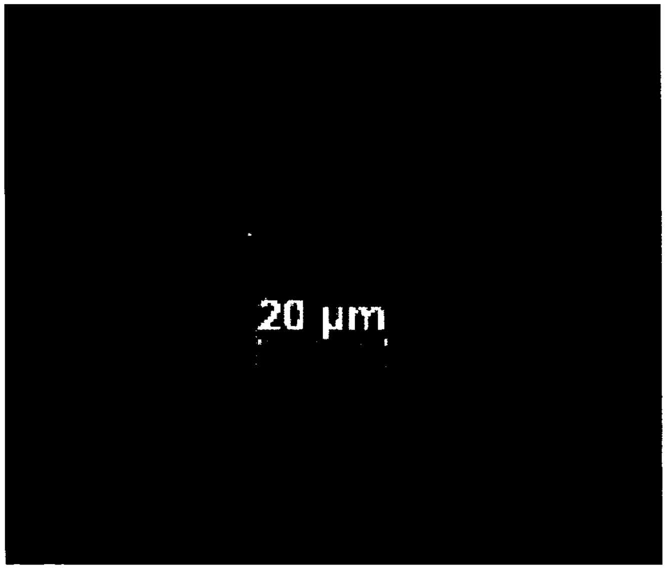

Figure 75.1: Damaged Starch 1

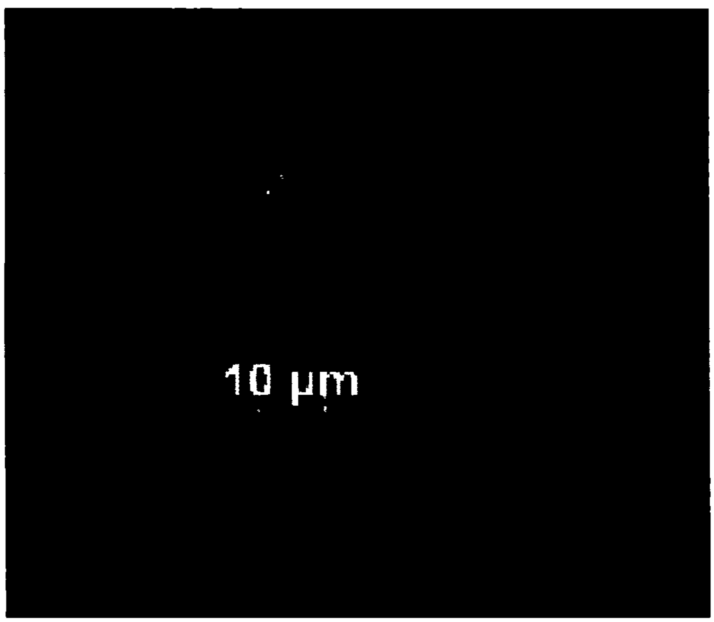

Figure 75.2: Damaged Starch 1 (under polarize light)

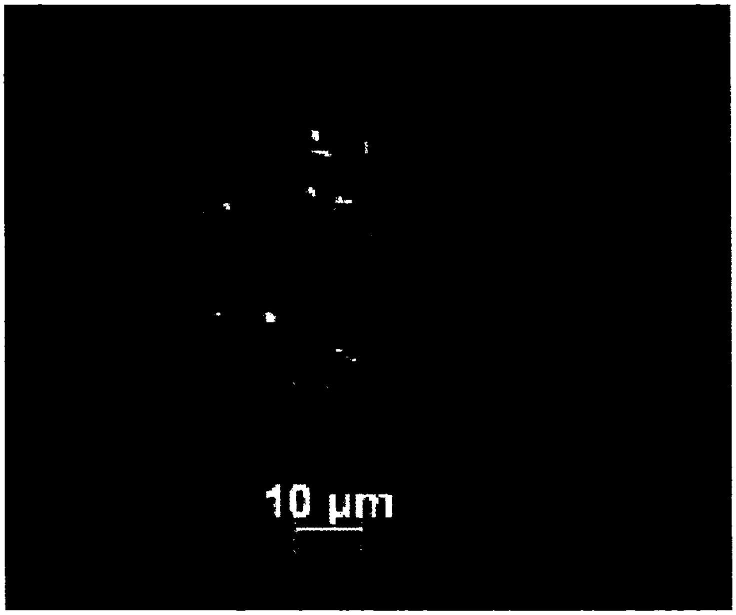

Figure 75.3: Damaged Starch 1 (on rotation)

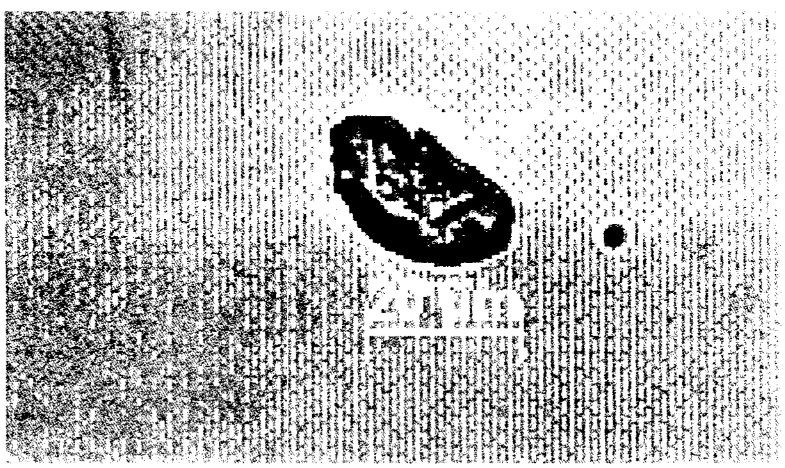

Figure 75.4: Damaged Starch 2

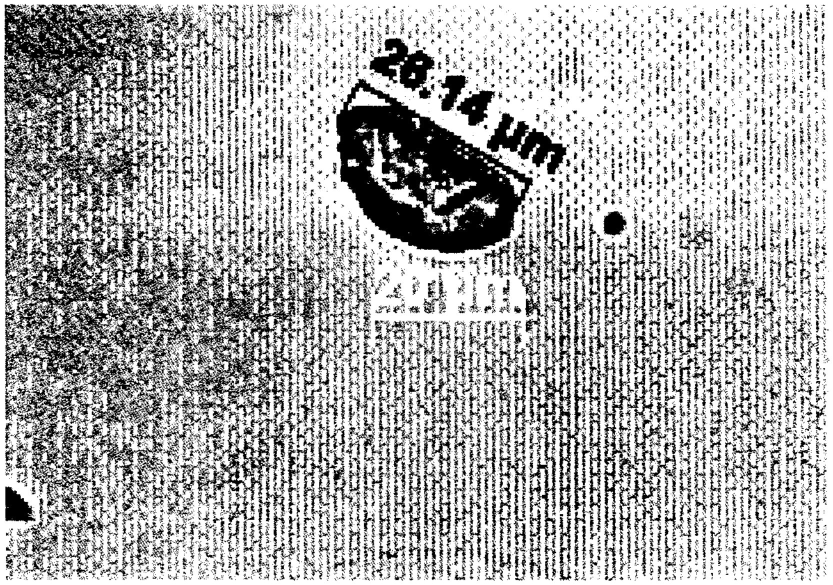

Figure 75.5: Damaged Starch 2 (measurement)

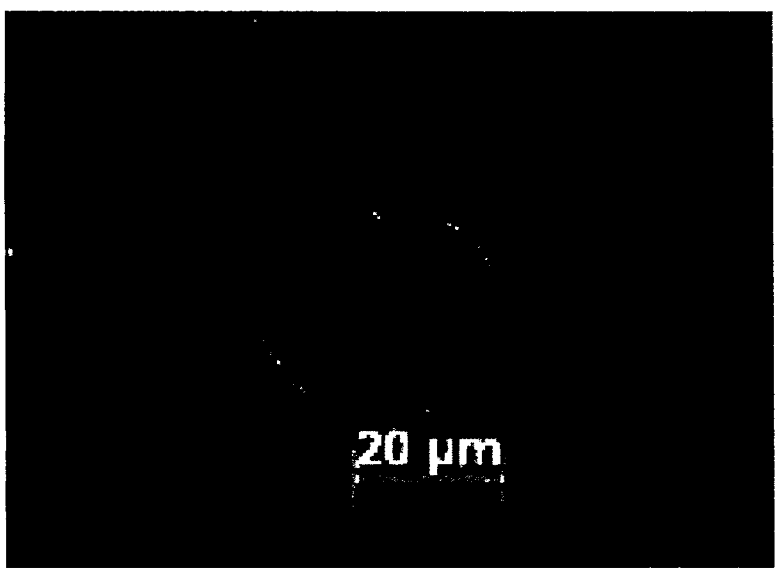

Figure 76.1: Starch from cf. *Zingiber*

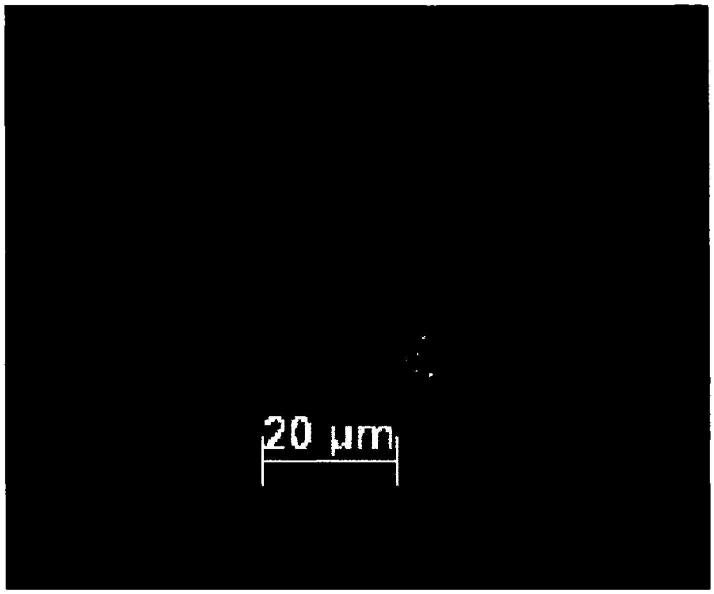

Figure 76.2: Starch from cf. *Zingiber* (under polarize)

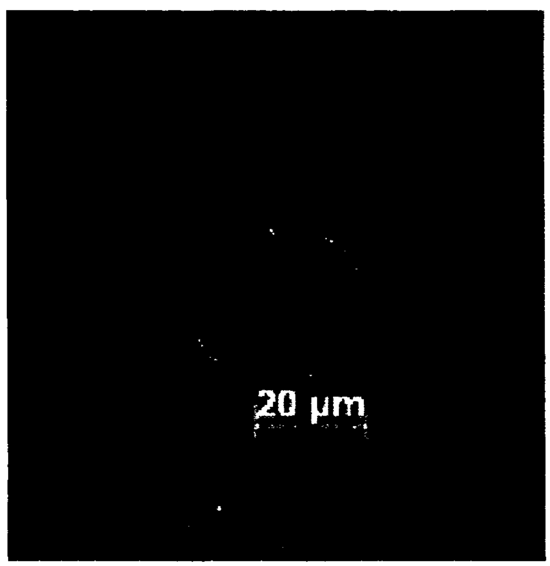

Figure 76.3: Starch from cf. *Zingiber* (measurement)

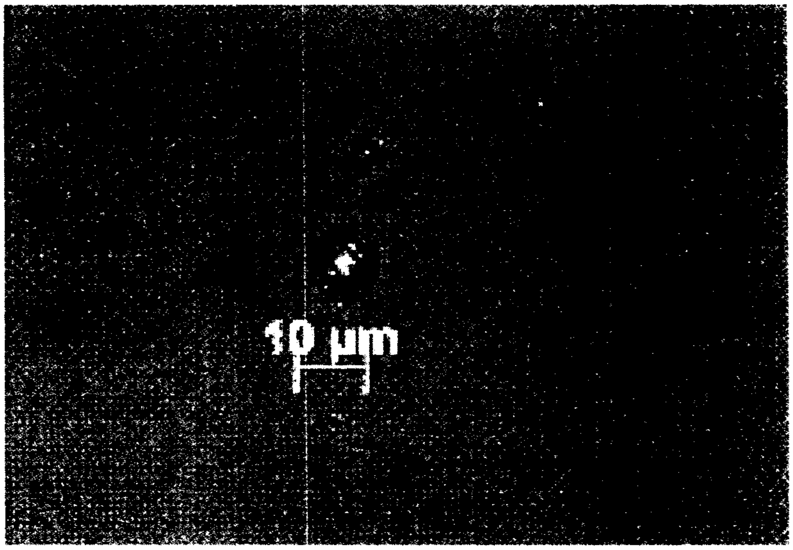

Figure 76.4: Compound Starch

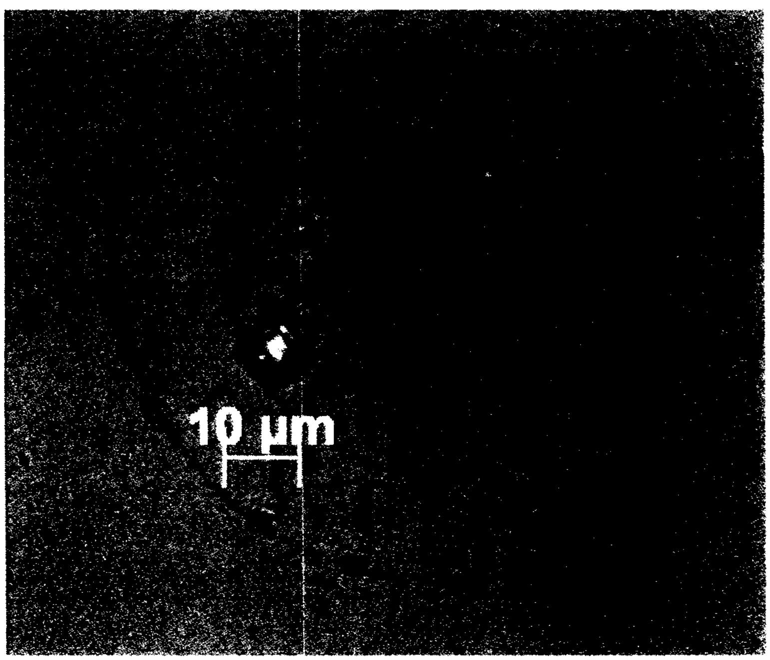

Figure 76.5: Compound Starch (measurement)

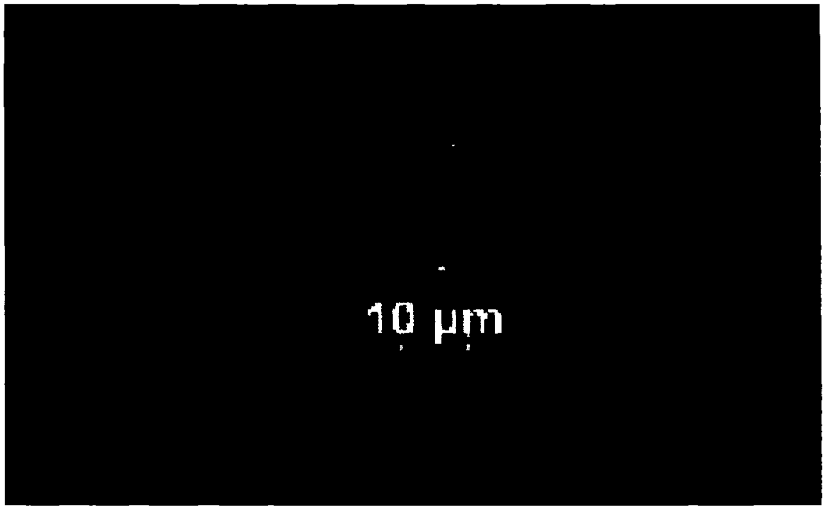

Figure 76.6: Compound Starch (under polarize light)

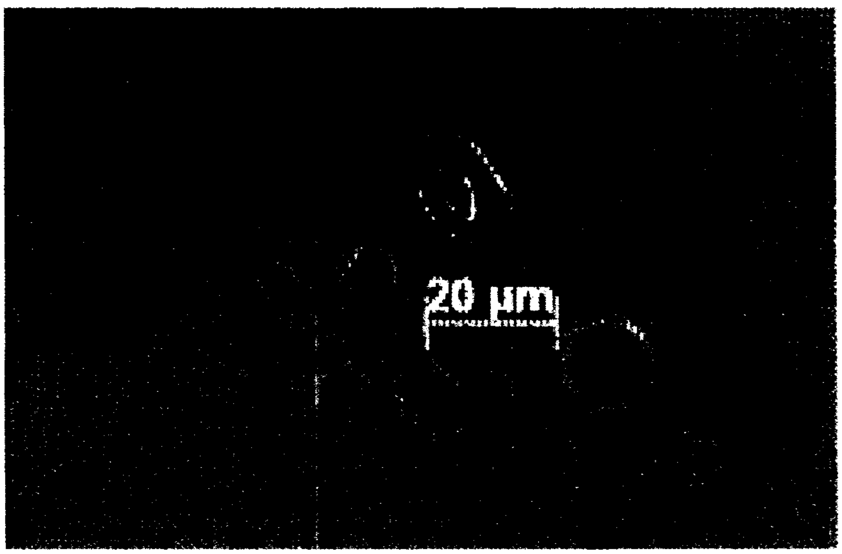

Figure 76.7: Starch Grain from of cf. *Solanum*

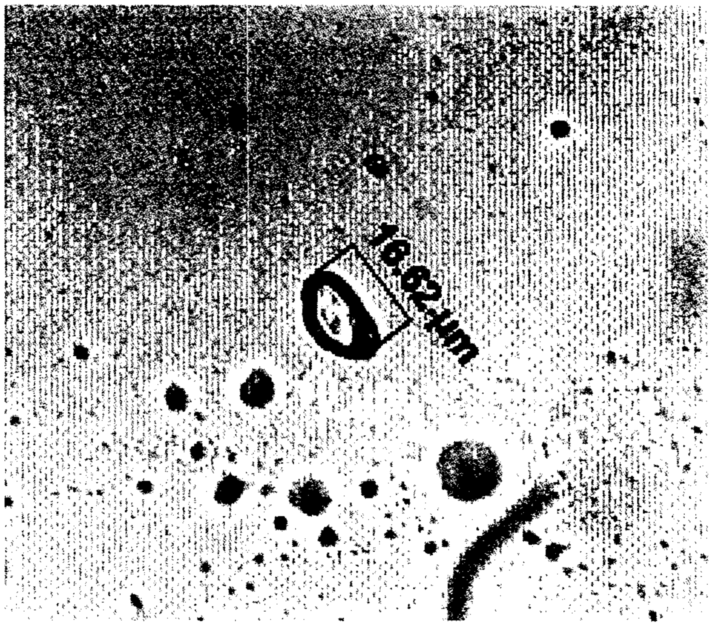

Figure 76.8: Starch Grain from pericarp of cf. *Solanum* (measurement)

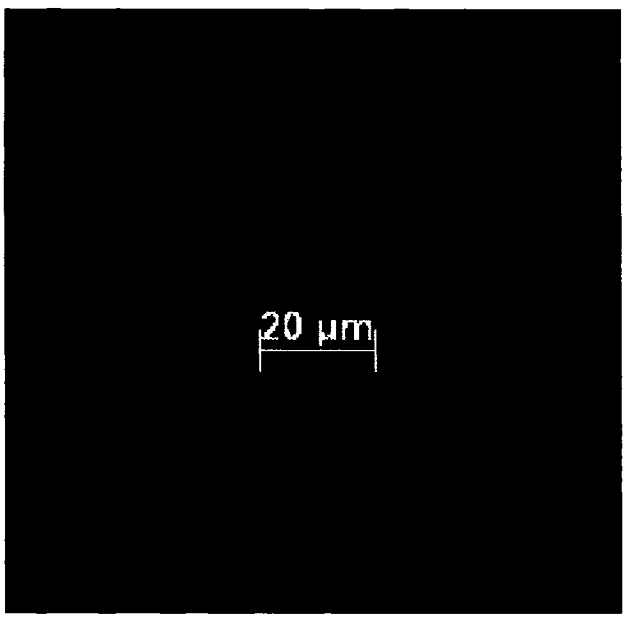

Figure 76.9: Starch Grain from pericarp of cf. *Solanum* (under polarize)

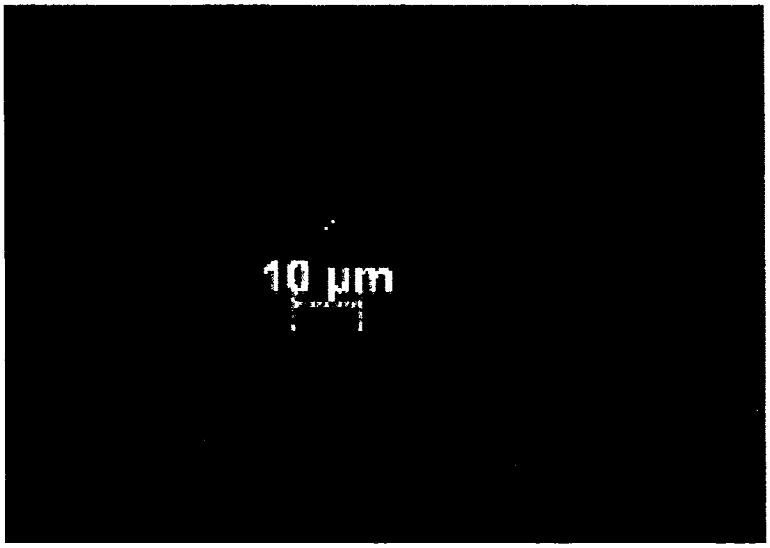

Figure 76.10: Starch Grain from Seed of cf. *Solanum*

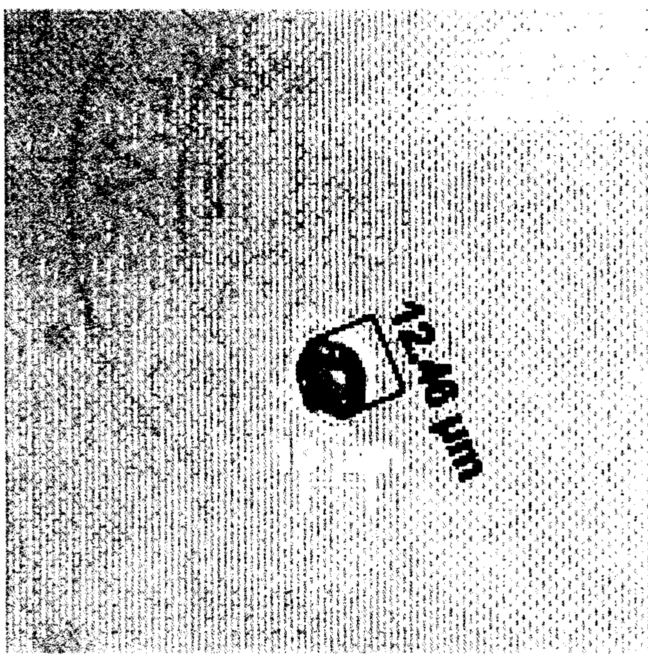

Figure 77.1: Damaged Starch (measurement)

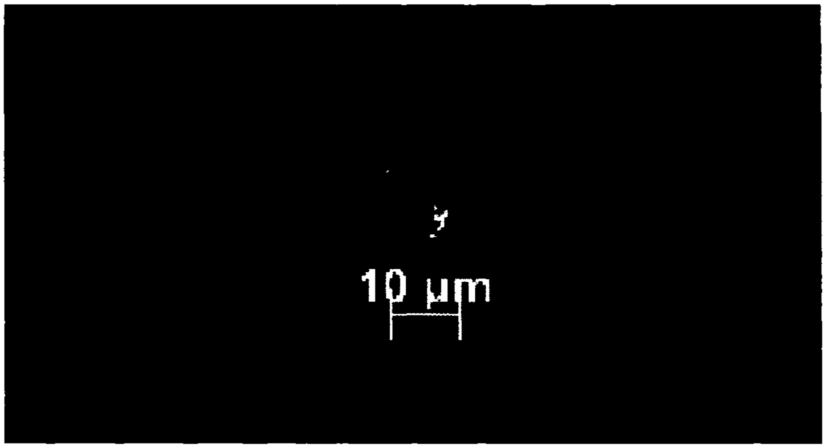

Figure 77.2: Damaged Starch (under polarize light)

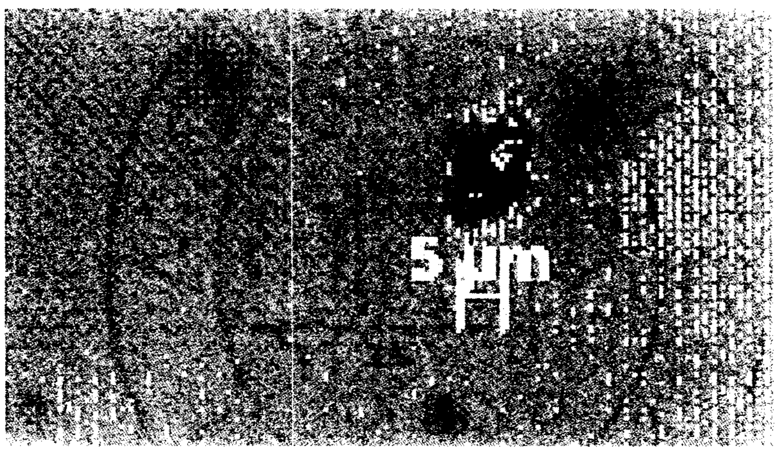

Figure 77.3: Compound Starch

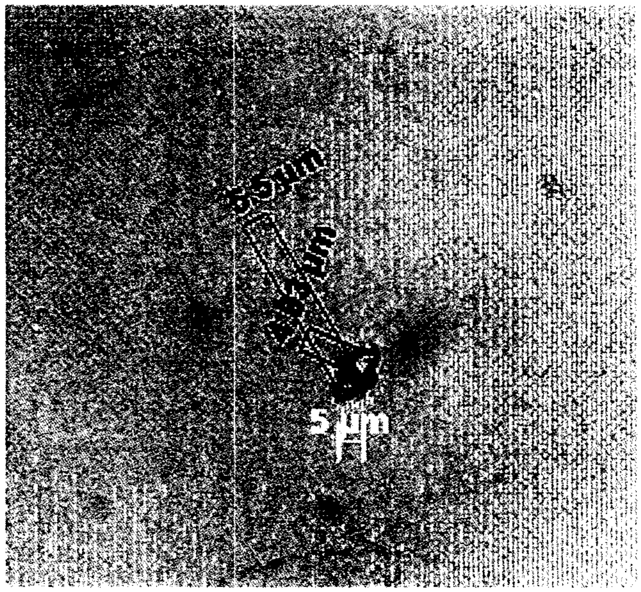

Figure 77.4: Compound Starch (measurement)

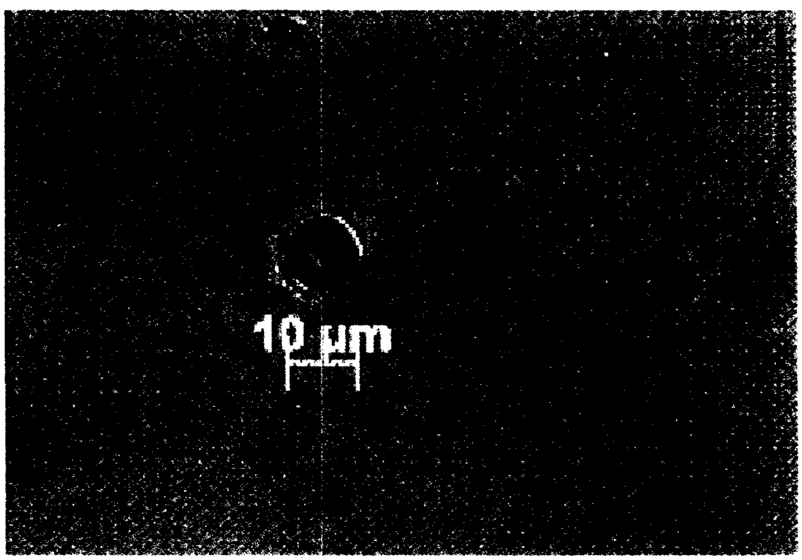

Figure 77.5: Starch from cf. *Vigna* sp.

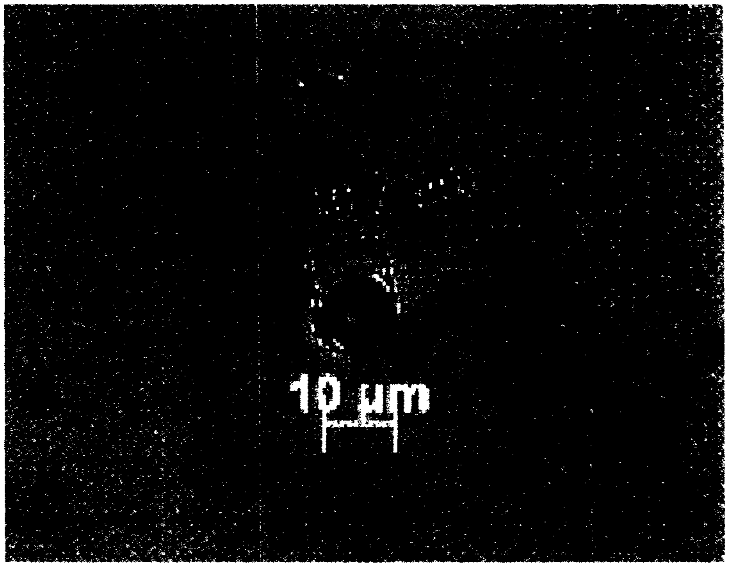

Figure 77.6: Starch from cf. *Vigna* sp. (measurement)

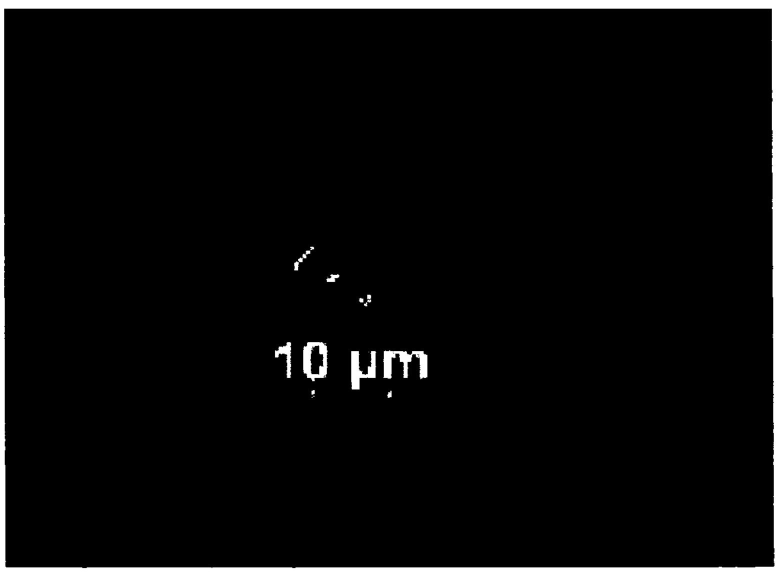

Figure 77.7: Starch from cf. *Vigna* sp. (under polarize light)

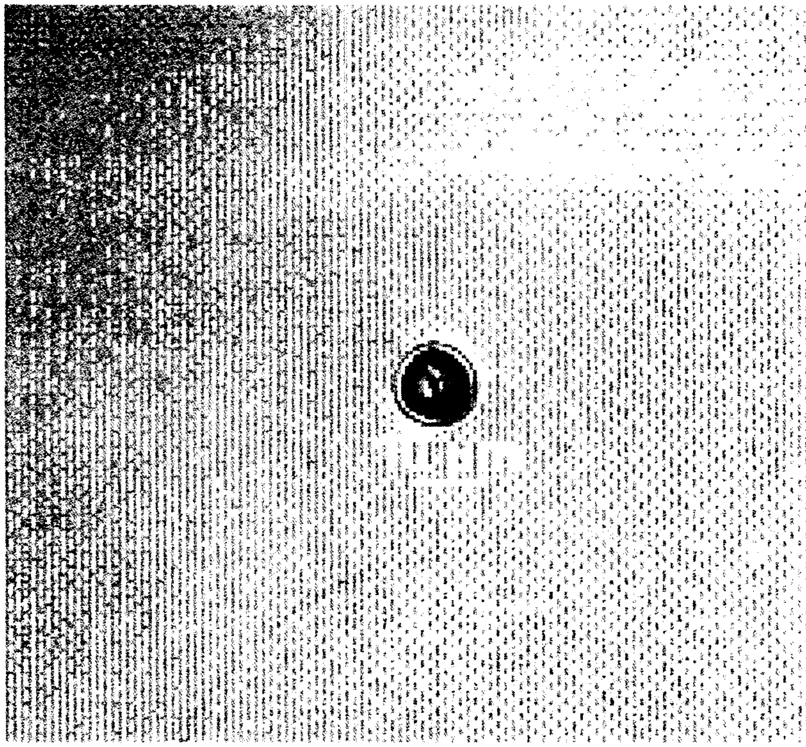

Figure 77.8: Starch from cf. *Vigna* sp. (characteristic V shaped fissures)

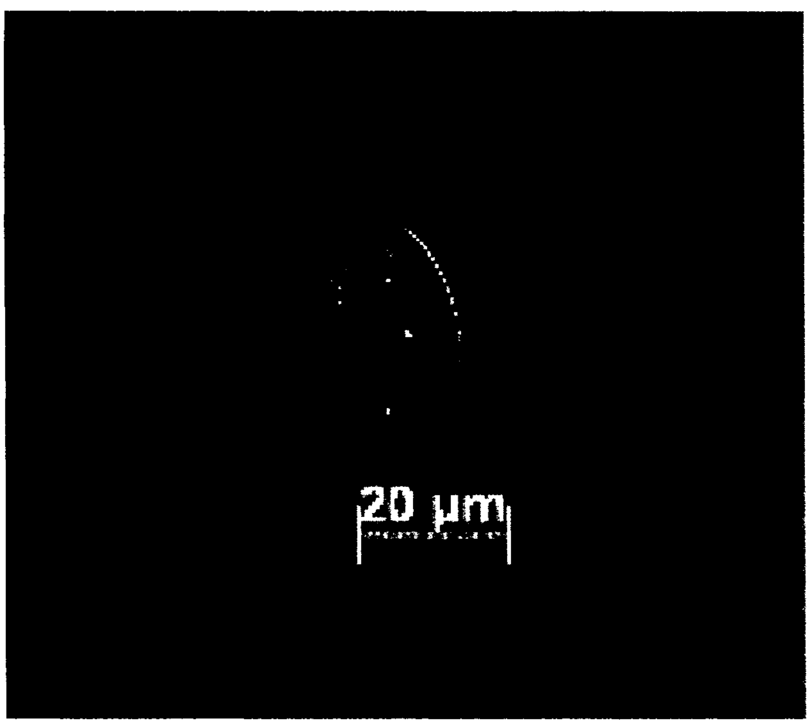

Figure 77.9: Starch from cf. *Macrotyloma*

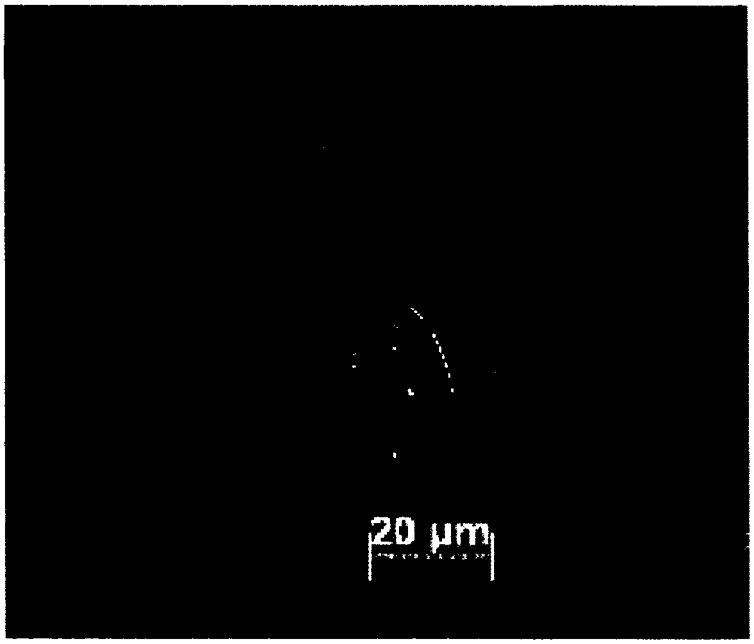

Figure 77.10: Starch from cf. *Macrotyloma* (measurement)

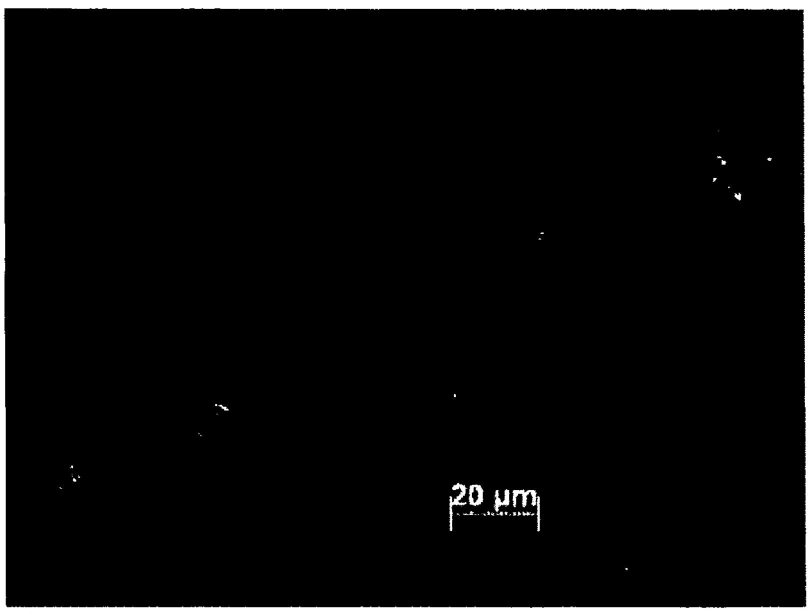

Figure 78.1: Starch Granules

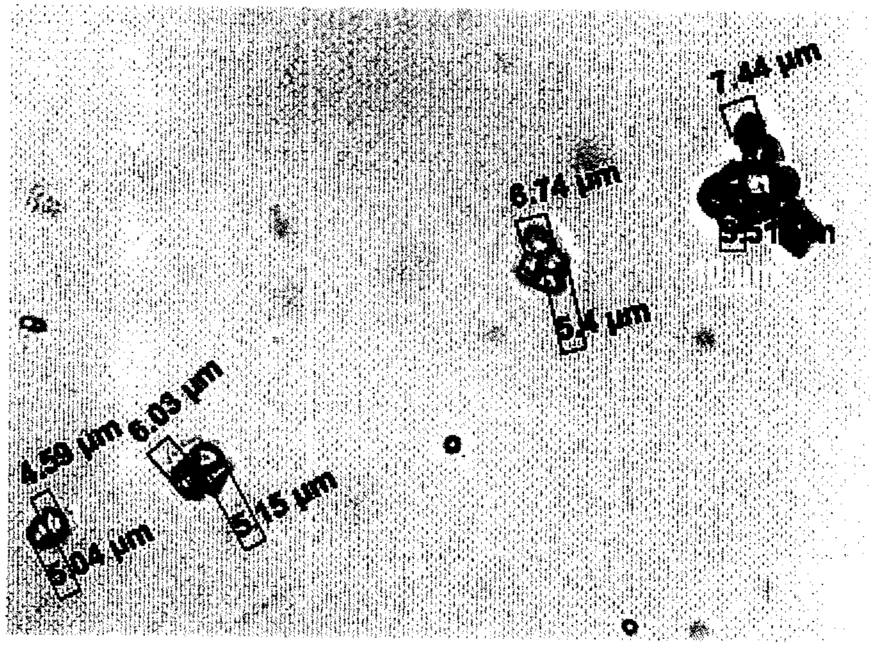

Figure 78.2: Starch Granules (measurement)

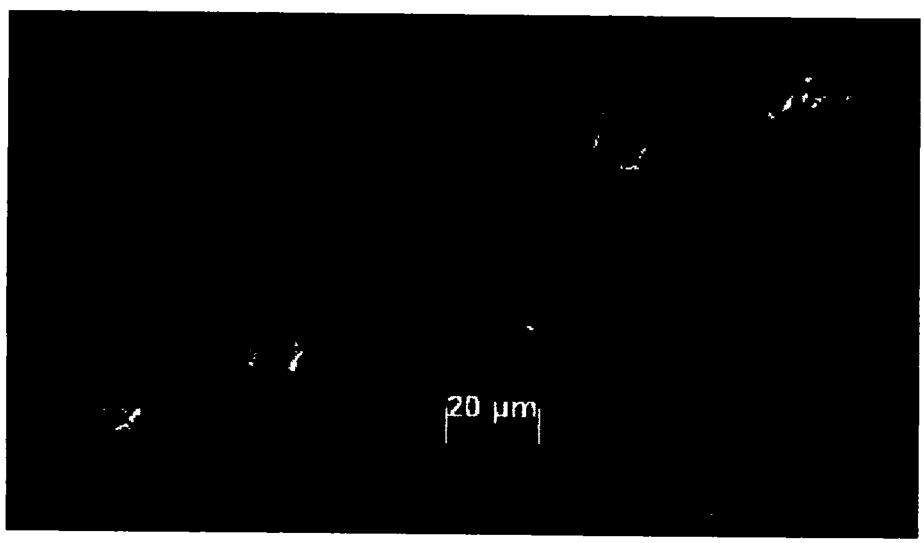

Figure 78.3: Starch Granules (under polarize light)

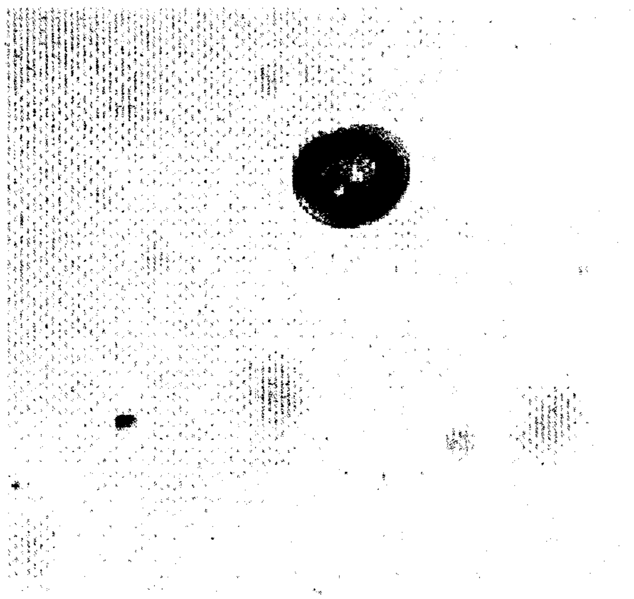

Figure 78.4: Unknown Bean Starch

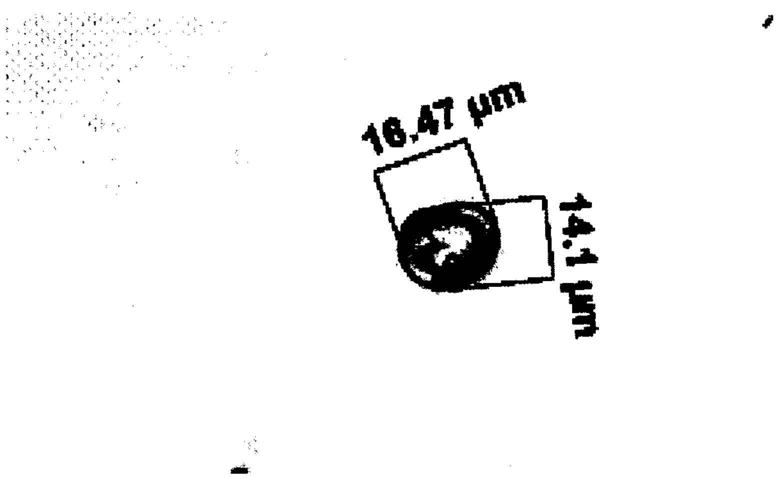

Figure 78.5: Unknown Bean Starch (under polarize light)

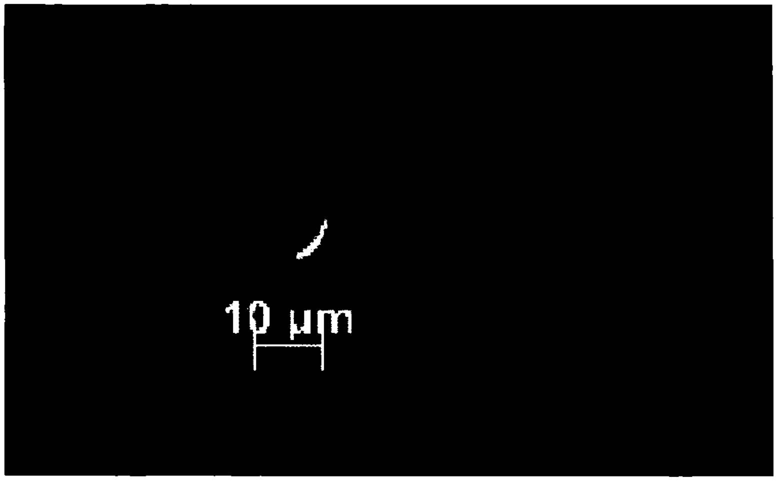

Figure 78.6: Unknown Bean Starch (under polarize light)

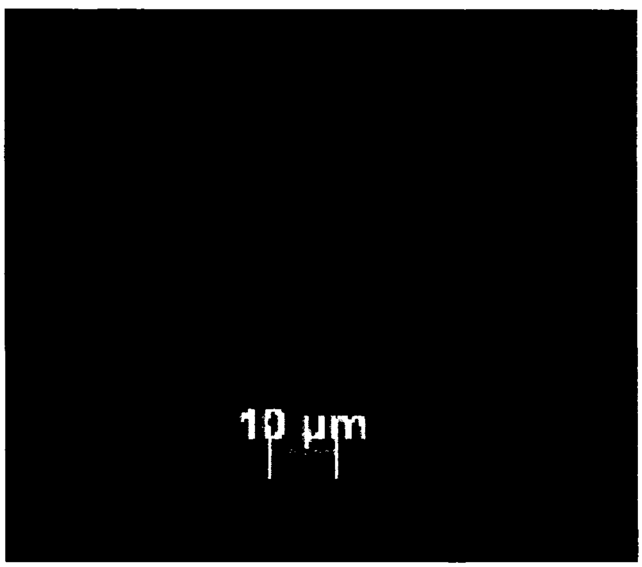

Figure 79.1: Starch from cf. *Mangifera*

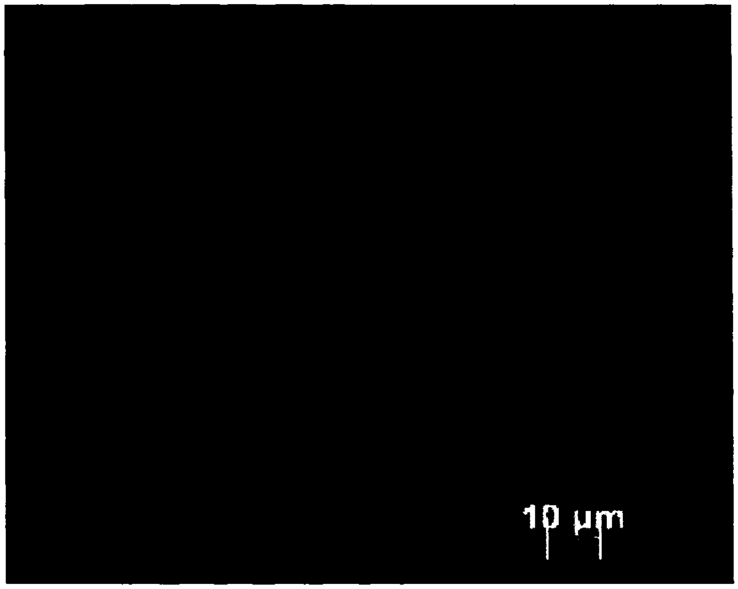

Figure 79.2: Starch from cf. *Mangifera* (measurement)

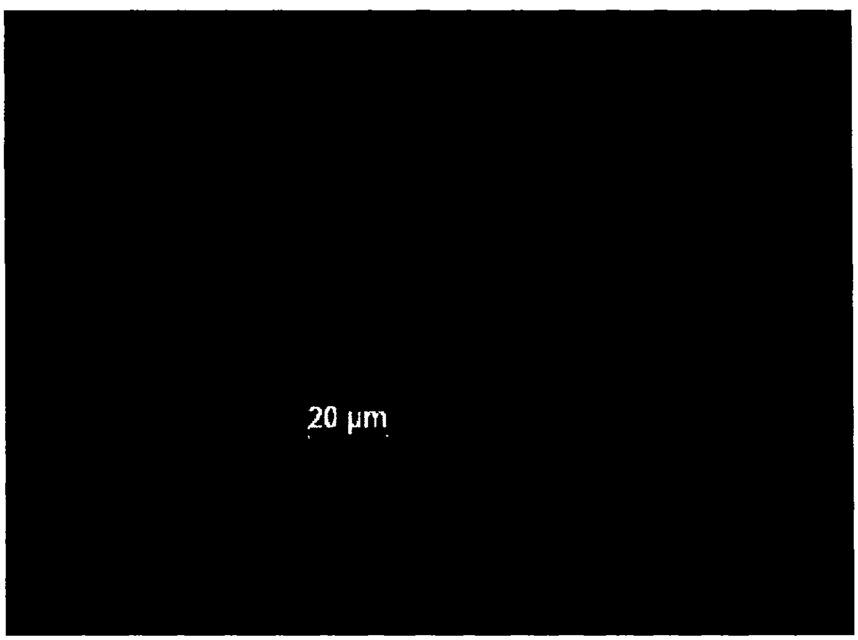

Figure 79.3: Starch from cf. *Mangifera*

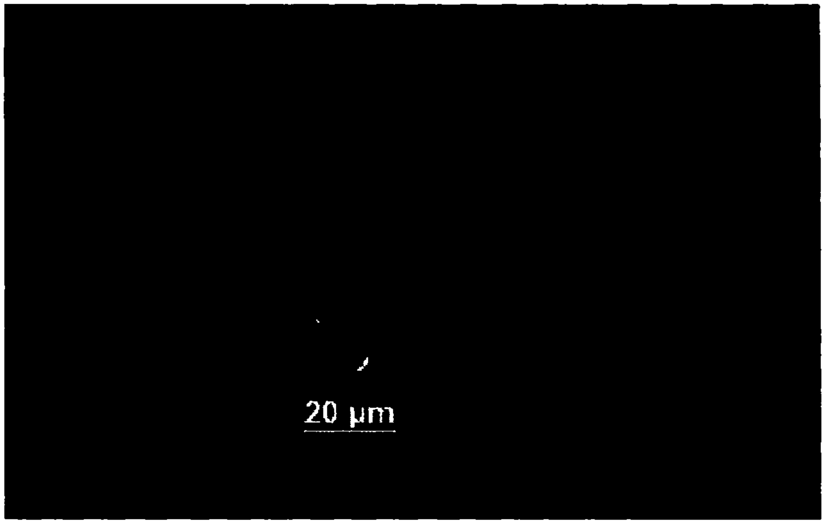

Figure 79.4: Starch from cf. *Mangifera* (under polarize light)

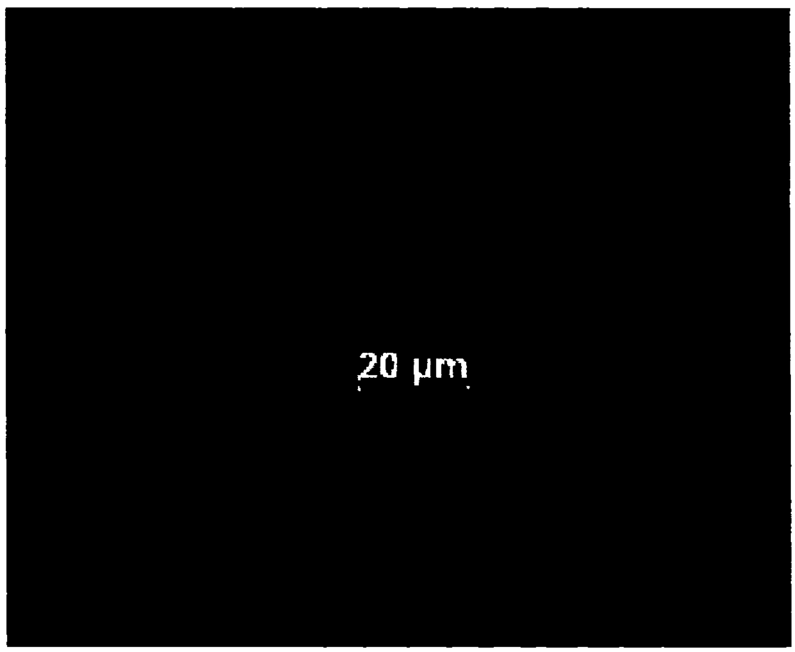

Figure 79.5: Starch from cf. *Mangifera* (measurement)

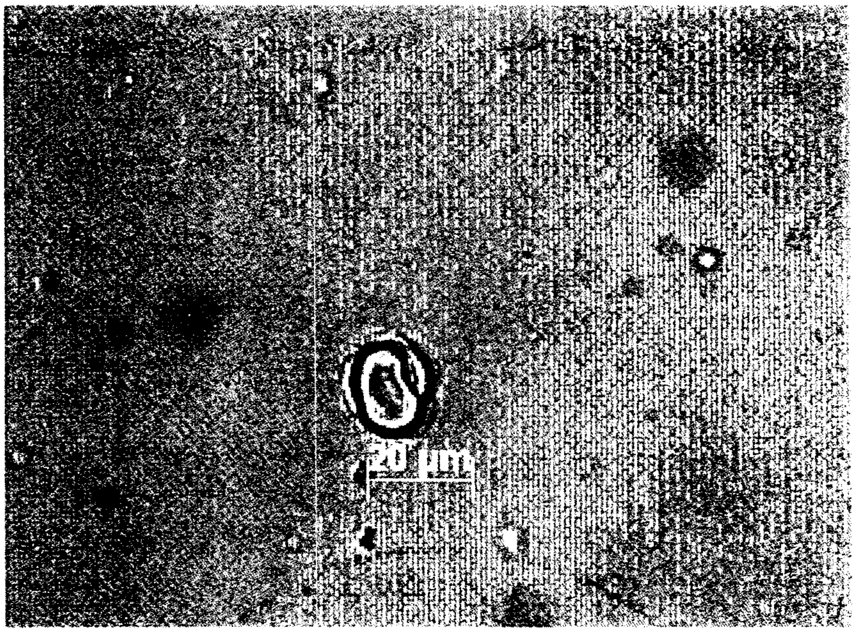

Figure 80.1: Elongate Starch from cf. *Solanum*

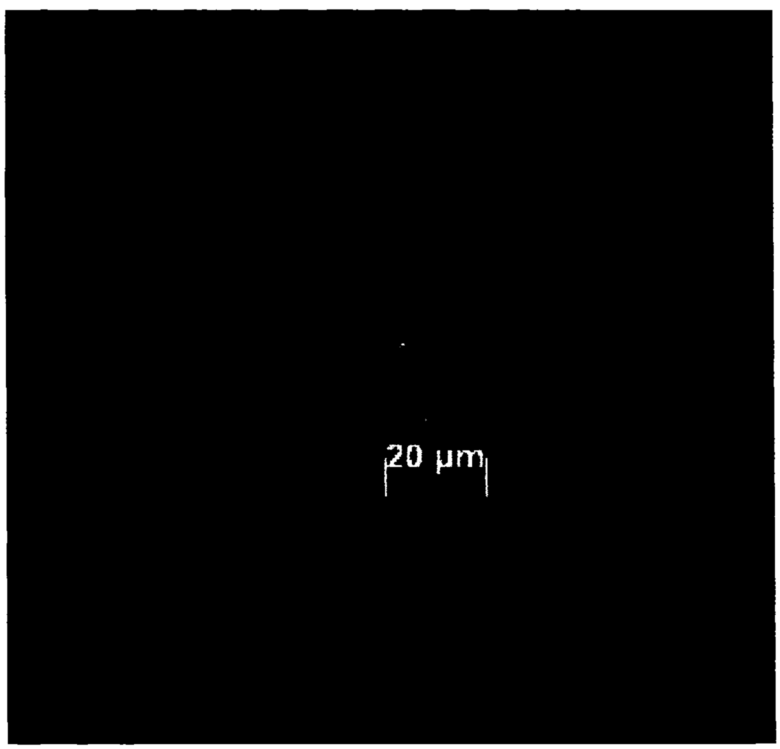

Figure 80.2: Elongate Starch from cf. *Solanum* (under polarize light)

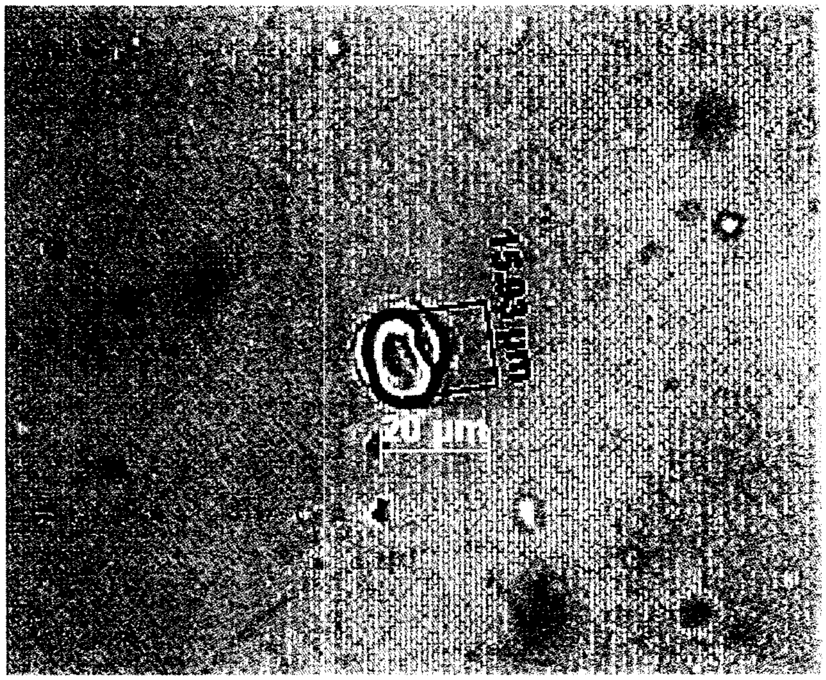

Figure 80.3: Elongate Starch from cf. *Solanum* (measurement)

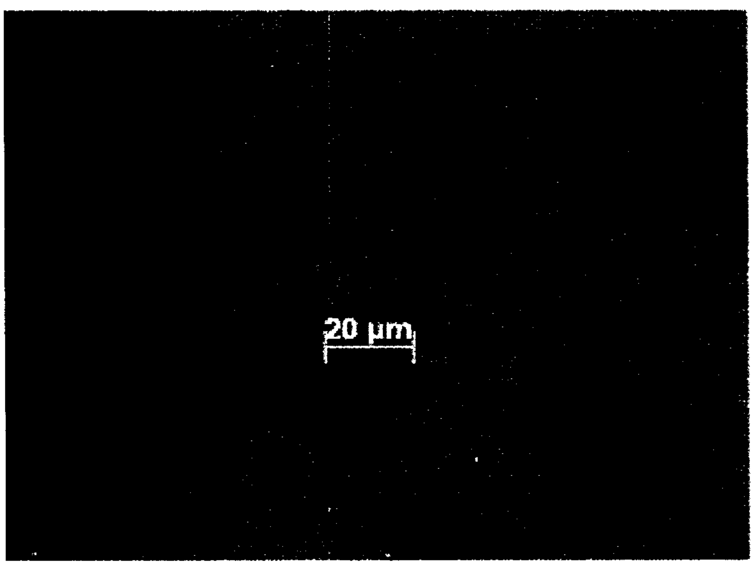

Figure 80.4: Elongate Starch from cf. *Solanum*

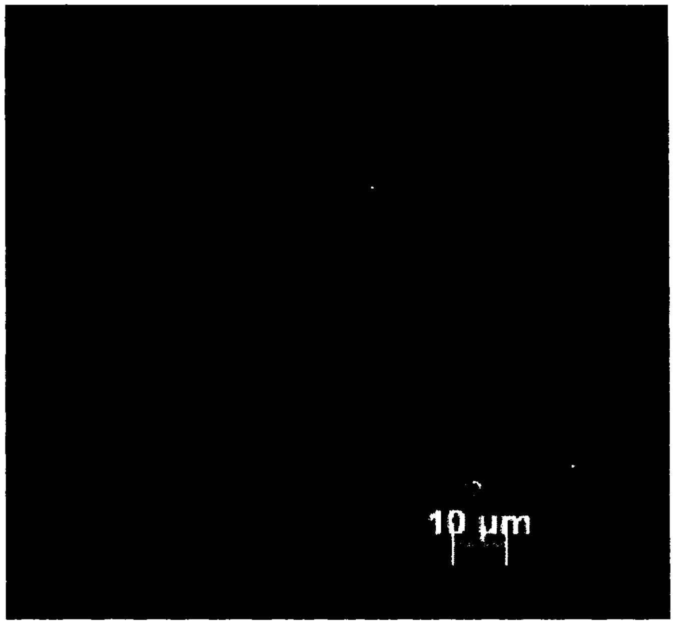

Figure 80.5: Unknown Starch 1

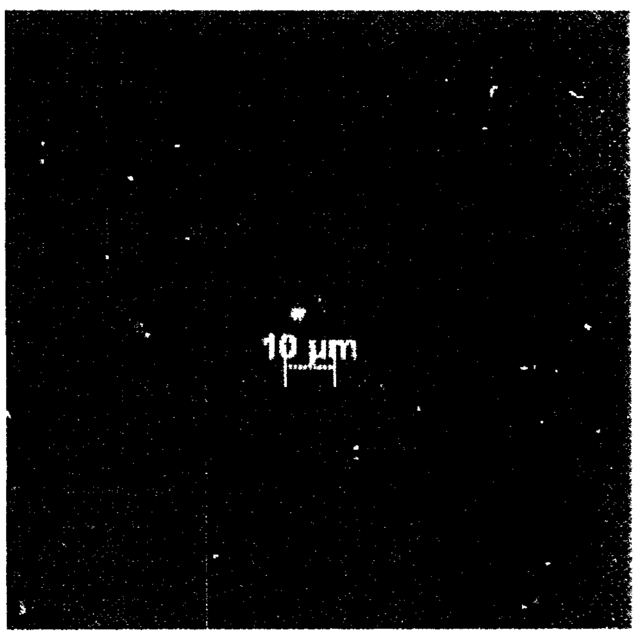

Figure 80.6: Unknown Starch 2

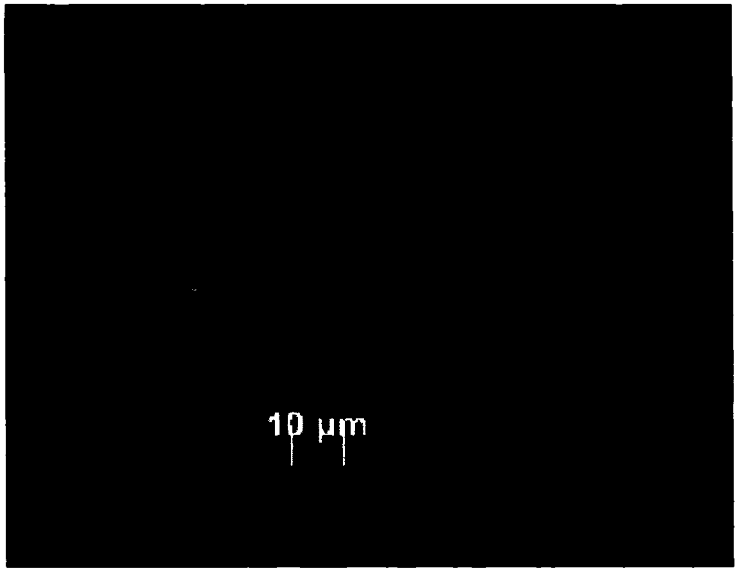

Figure 80.7: Unknown Starch 2 (under polarize light)

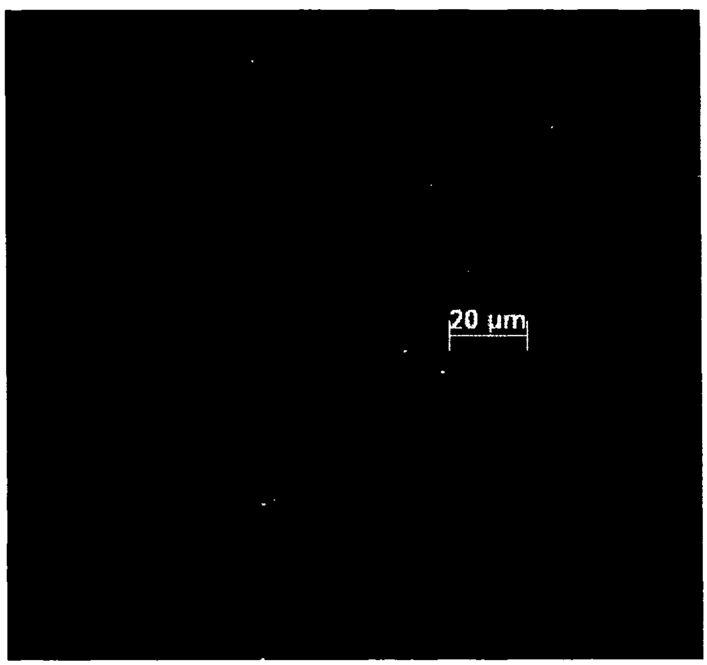

Figure 80.8: Elongate Starch from cf. *Solanum*

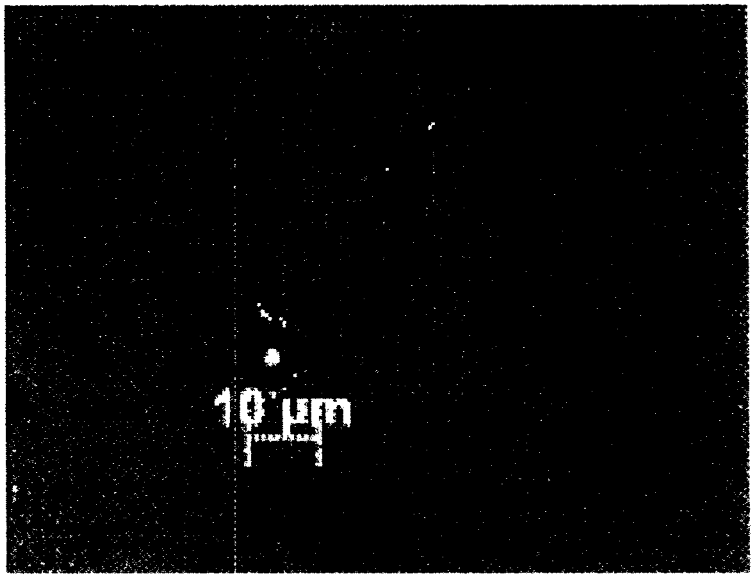

Figure 80.9: Unknown Starch 3

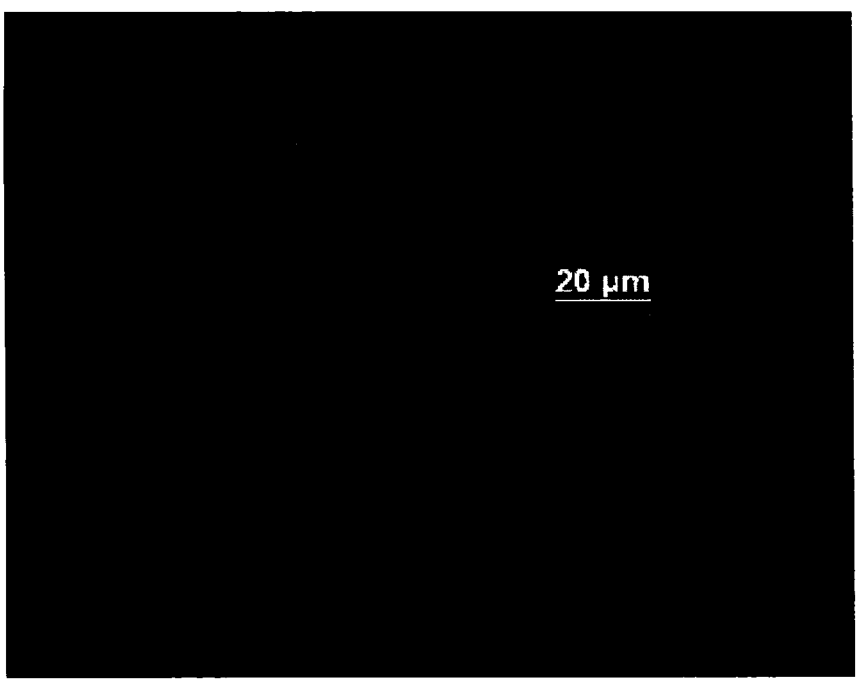

Figure 80.10: Bell Shaped Starch from seed of cf. *Solanum*

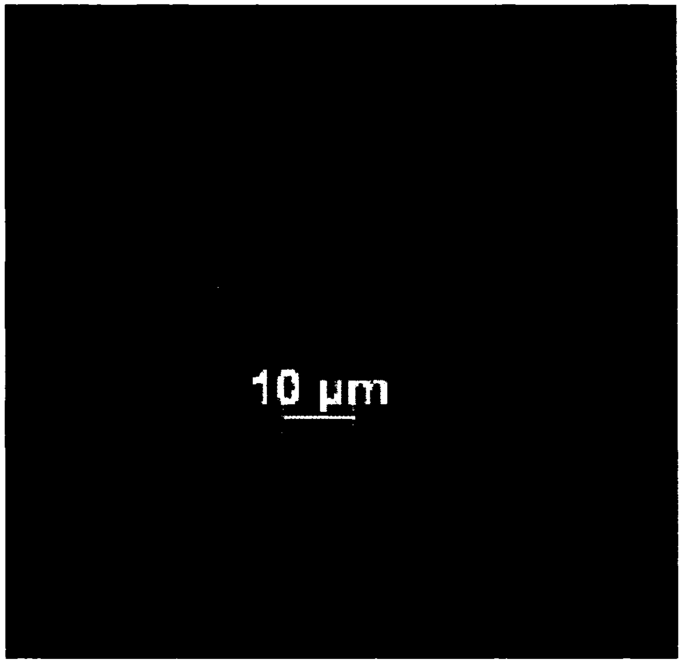

Figure 80.11: Damaged Starch

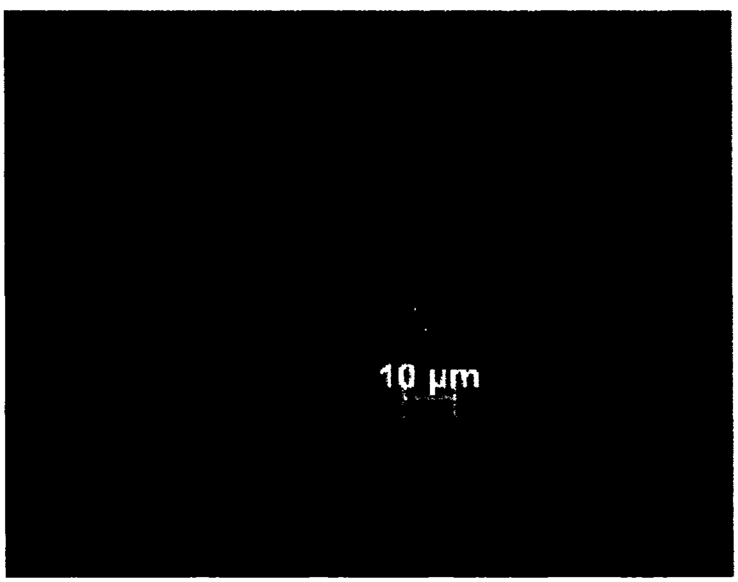

Figure 81.1: Compound Starches

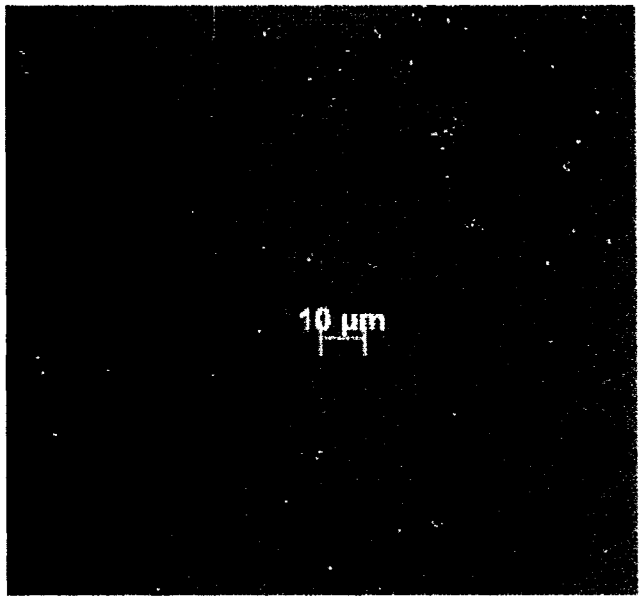

Figure 81.2: Compound Starch

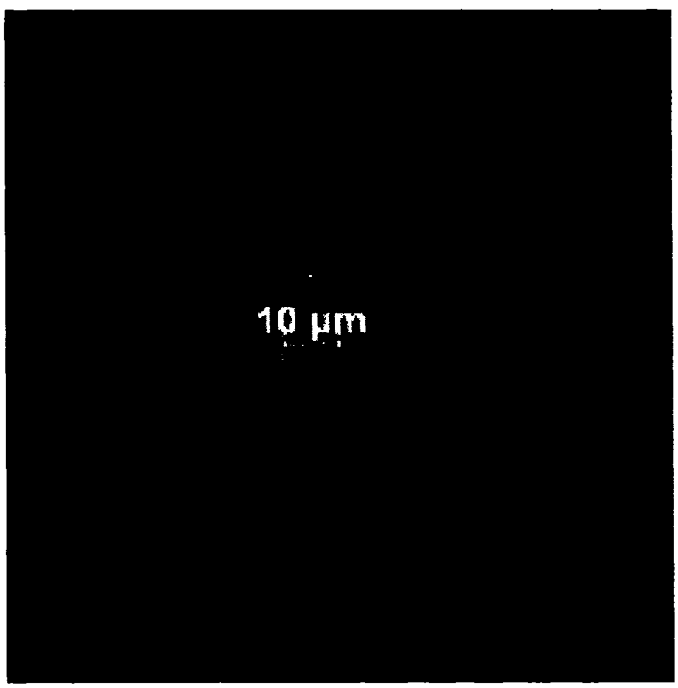

Figure 81.3: Unknown Starch

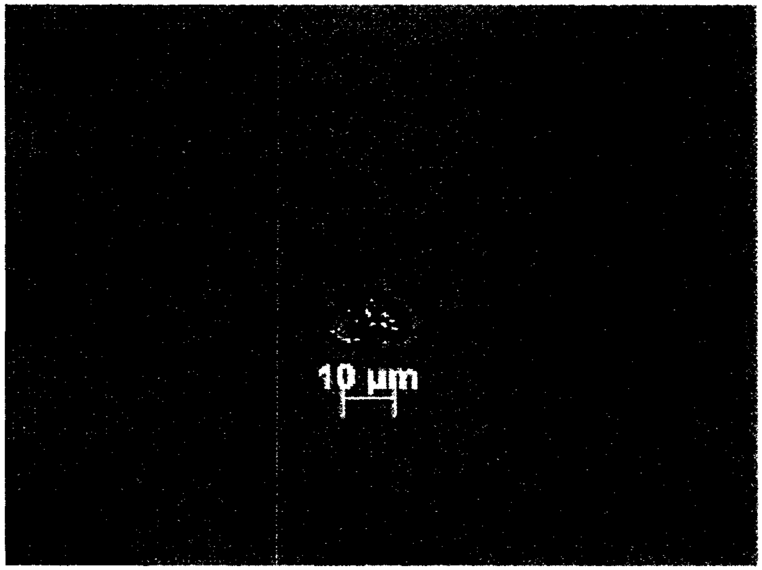

Figure 82.1: Starches from cf. *Sesamum*

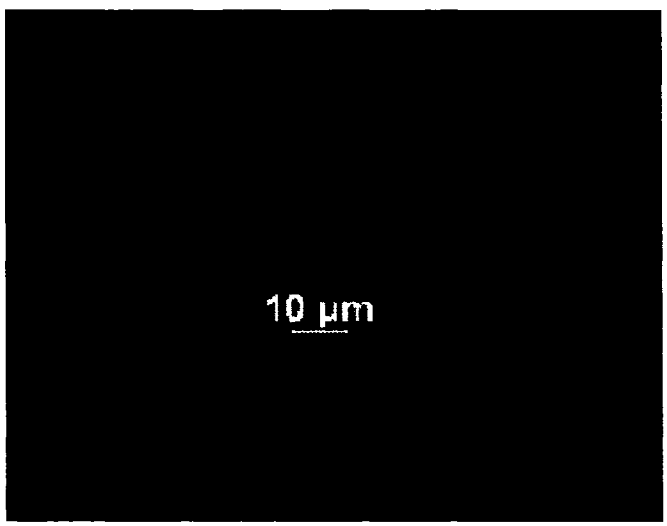

Figure 83.1: Compound Starch

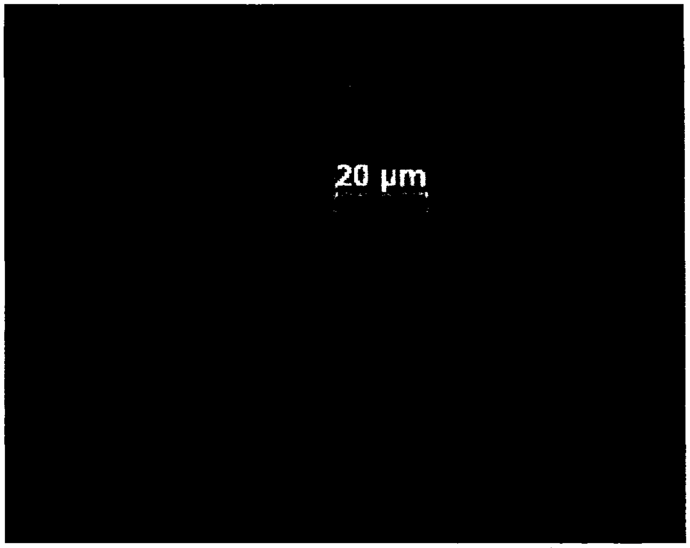

Figure 83.2: Compound Starches

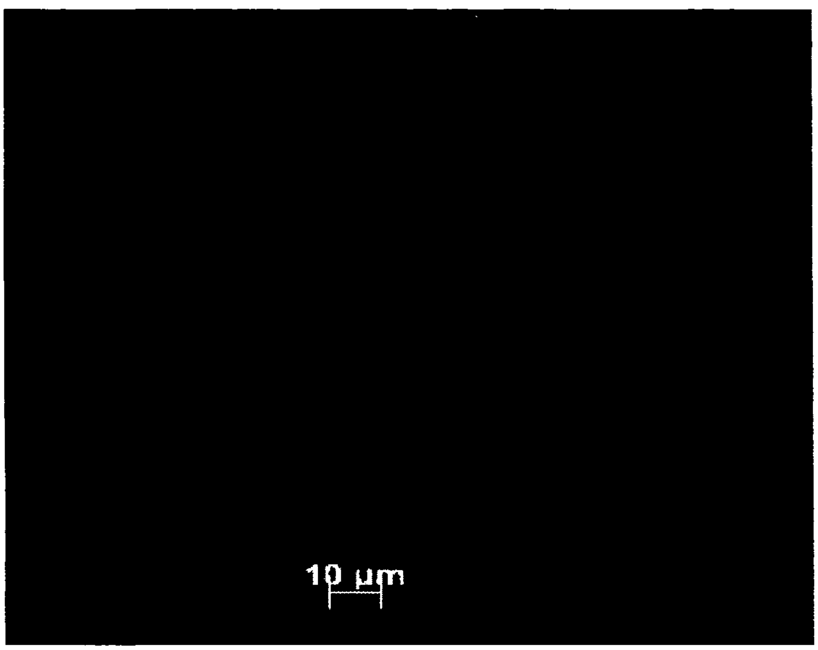

Figure 83.3: Compound Starches

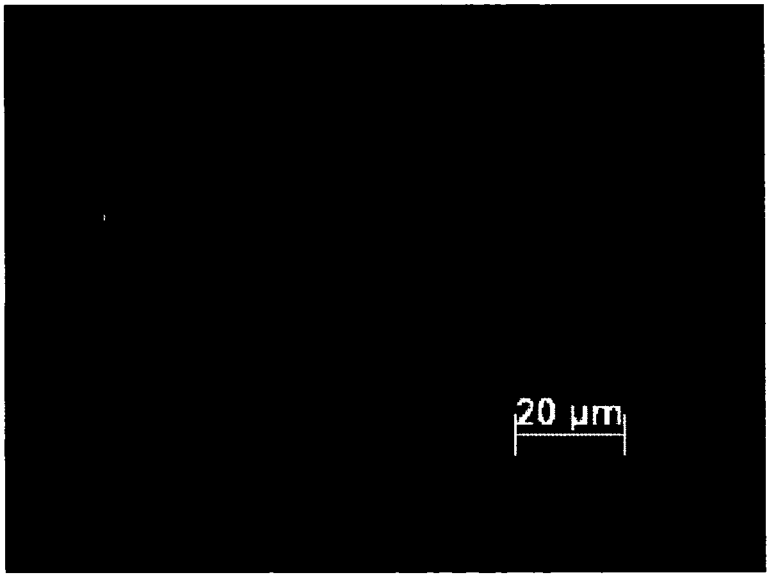

Figure 83.4: Bean Starch from cf. *Cajanus*
Also see in the figure Spherical Starch from cf. *Tamarindus* in three dimensions

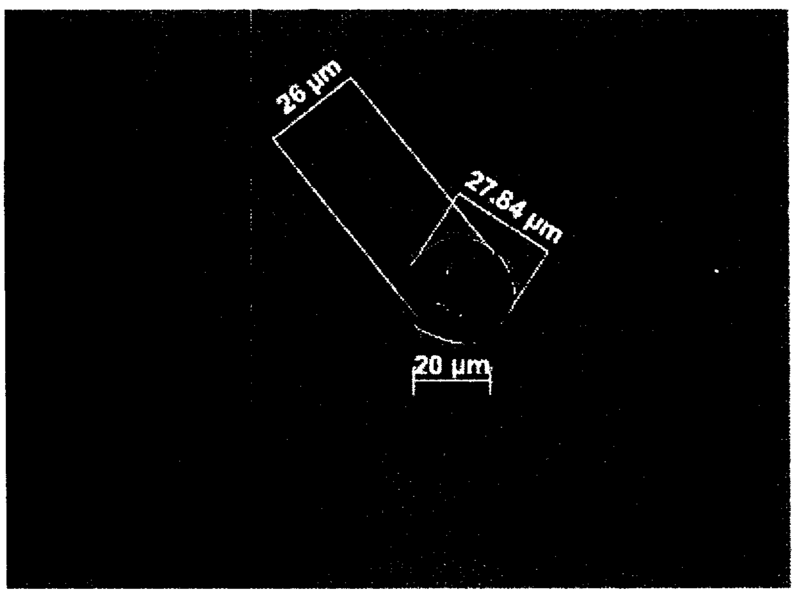

Figure 83.5: Bean Starch from cf. *Cajanus* (measurement)

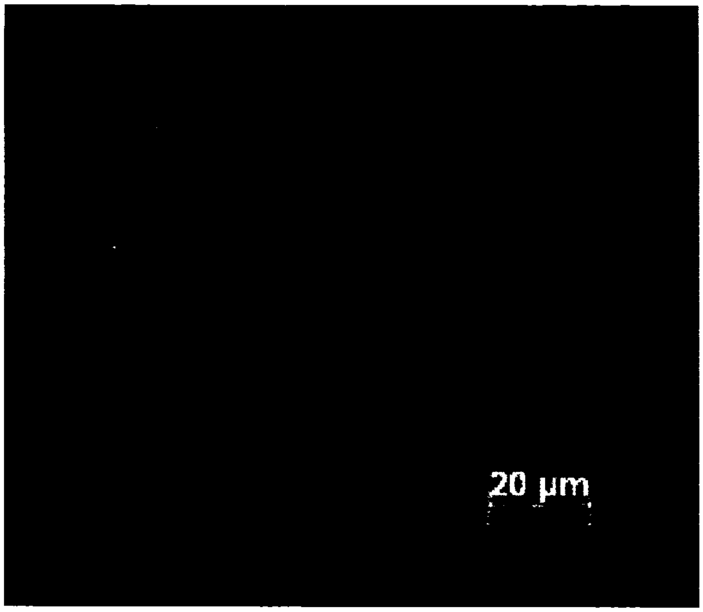

Figure 83.6: Compound Starches

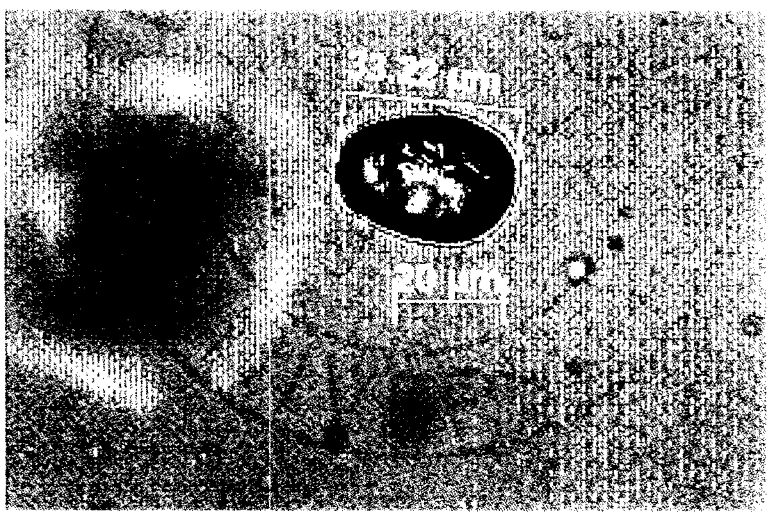

Figure 83.7: Bean Starch from cf. *Macrotyloma* (measurement)

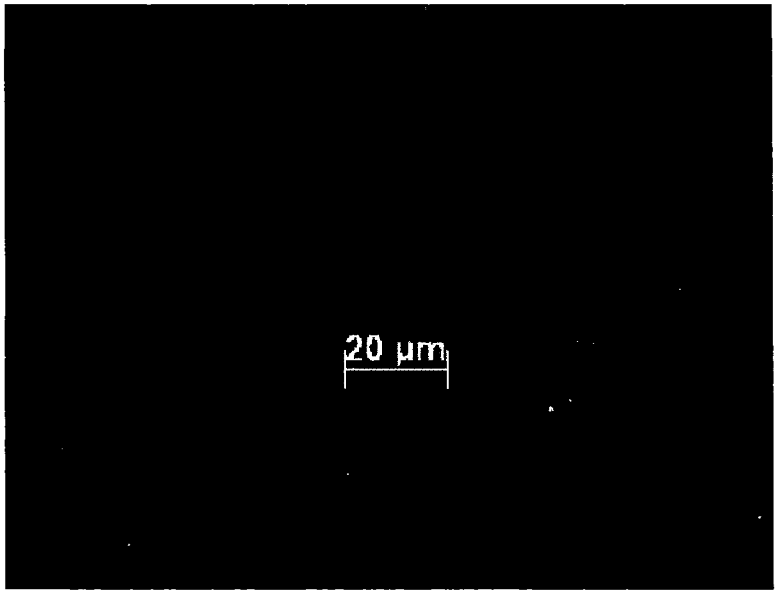

Figure 83.8: Damaged Unknown Bean Starch

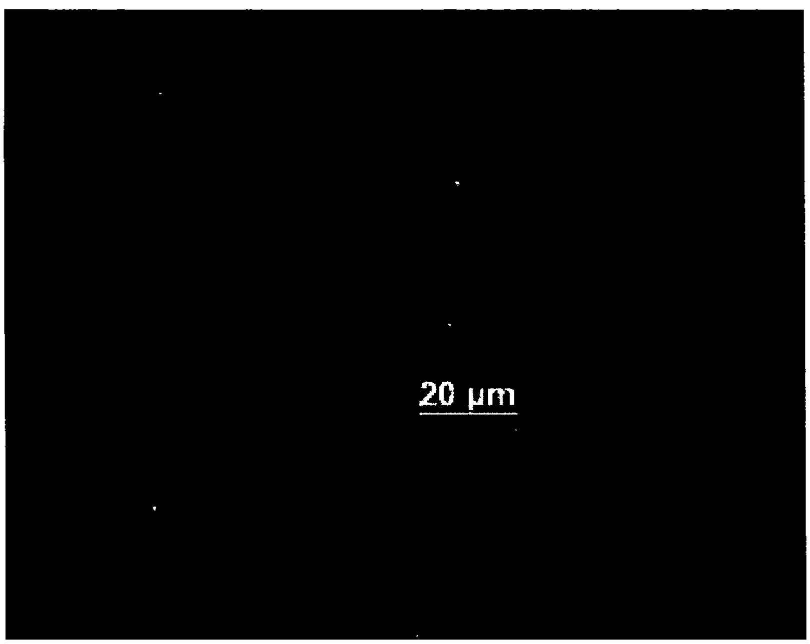

Figure 83.8: Starch from cf. *Eleusine*

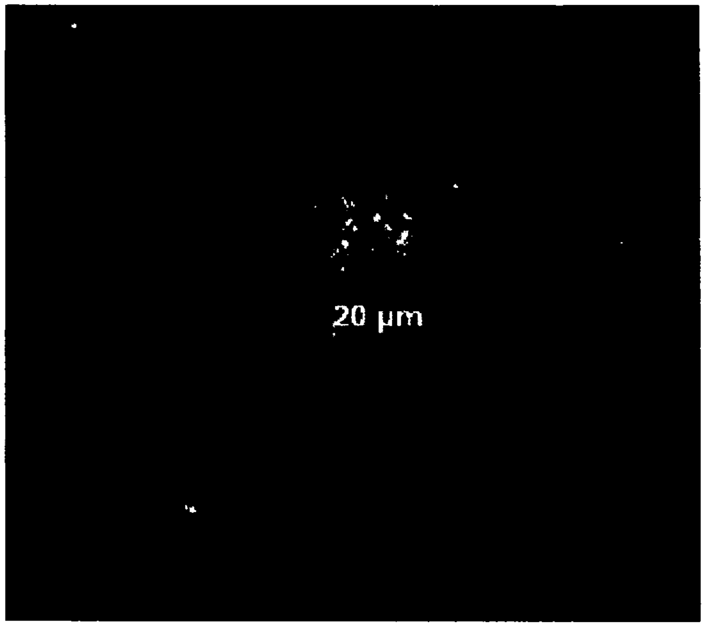

Figure 83.9: Starch from cf. *Eleusine* (under polarize light)

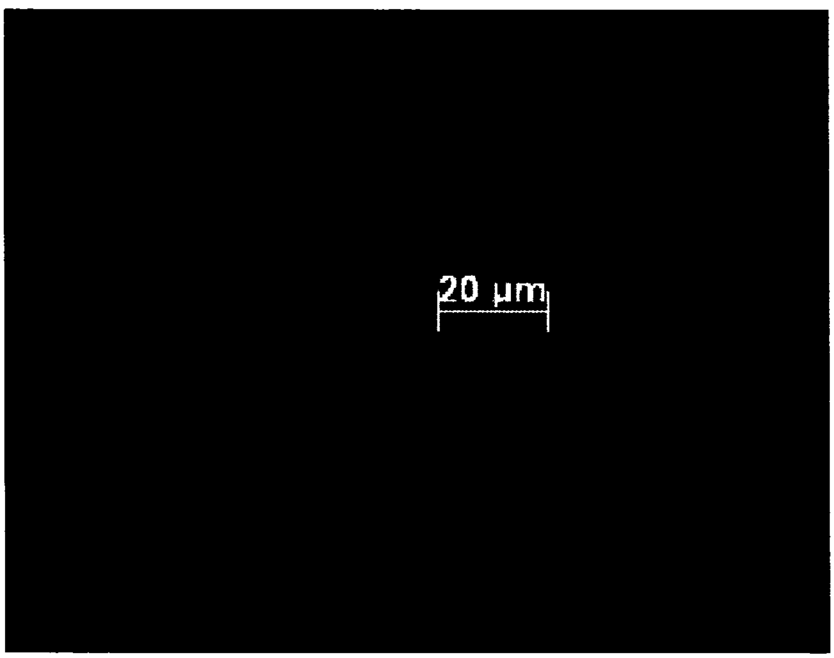

Figure 83.10: Starch from cf. *Eleusine* (on its back – on rotation)

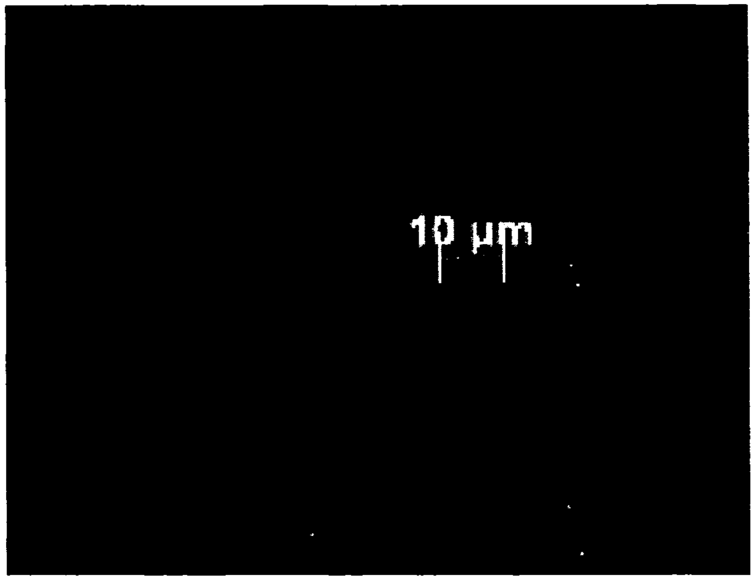

Figure 83.11: Starch from cf. *Tamarindus*

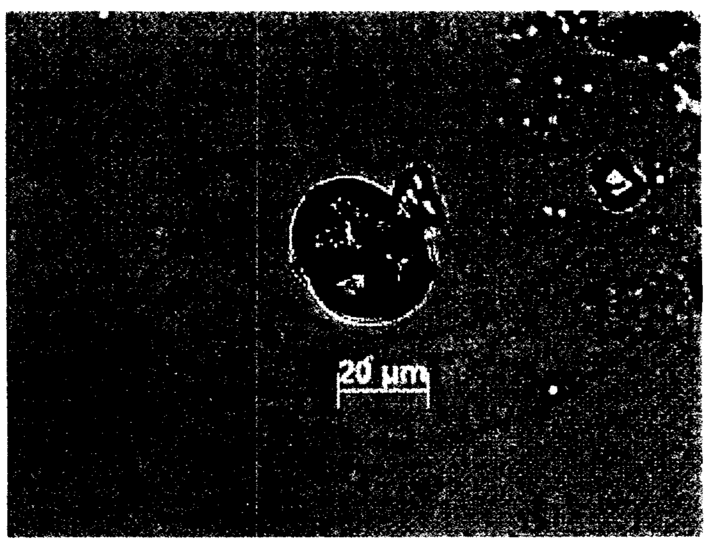

Figure 83.12: Bean Starch from cf. *Macrotyloma*

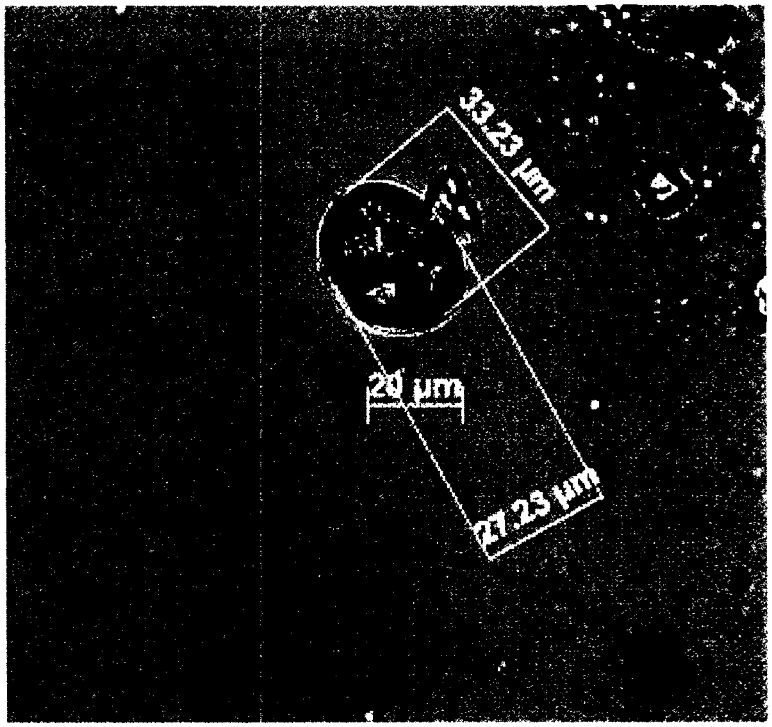

Figure 83.13: Bean Starch Bean Starch from cf. *Macrotyloma* (measurement)

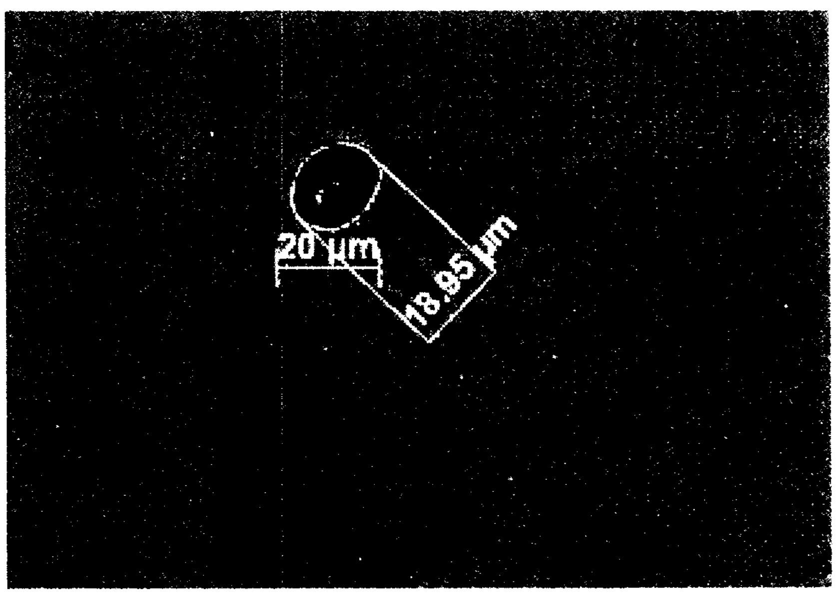

Figure 83.14: Starch from cf. *Phoenix* (measurement)

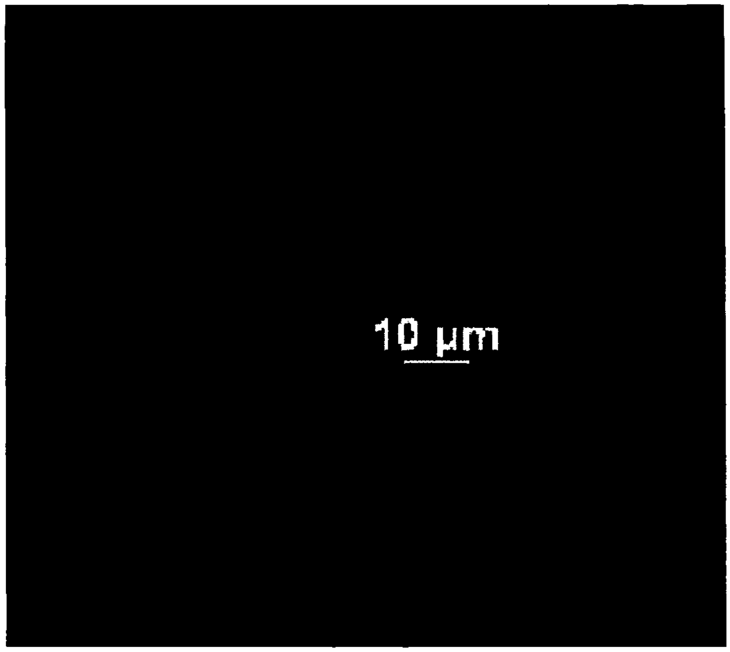

Figure 83.15: Compound Starches

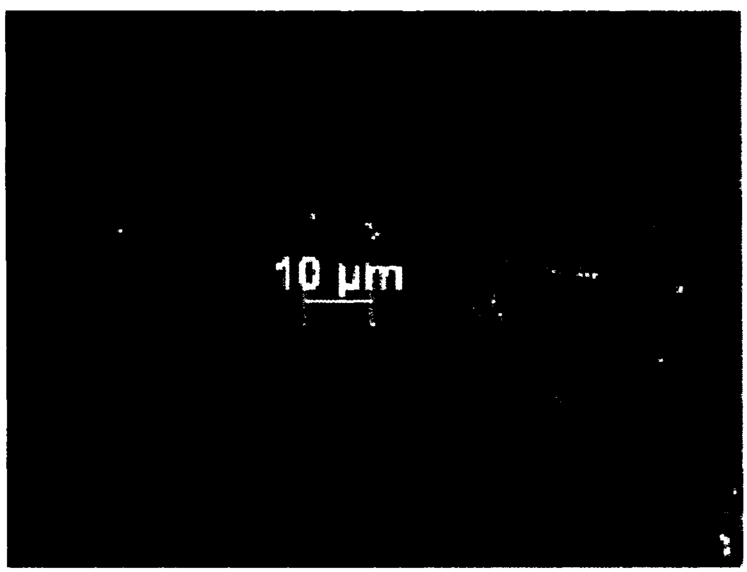

Figure 84.1: Starch from cf. *Sesamum*

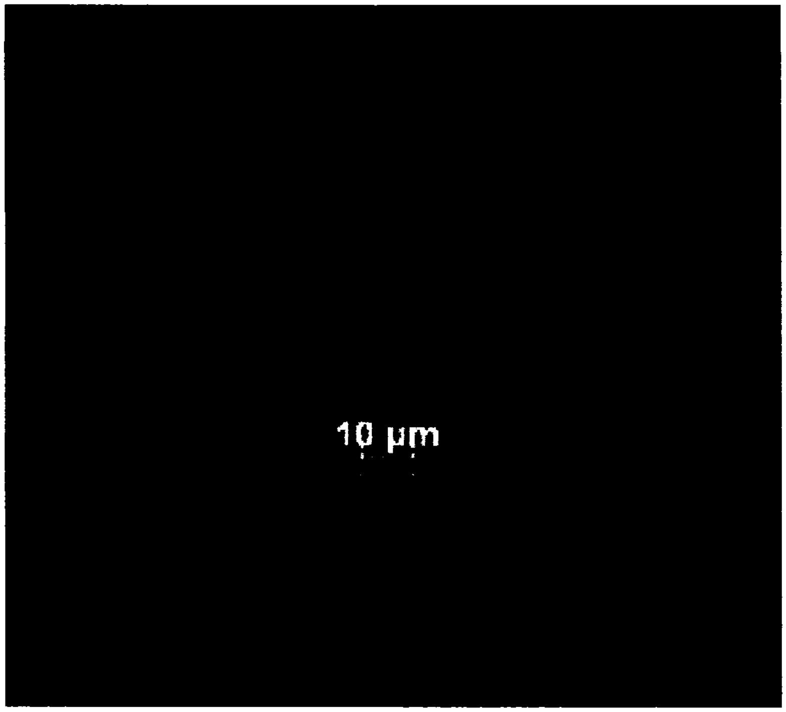

Figure 84.2: Starch from cf. *Phoenix*

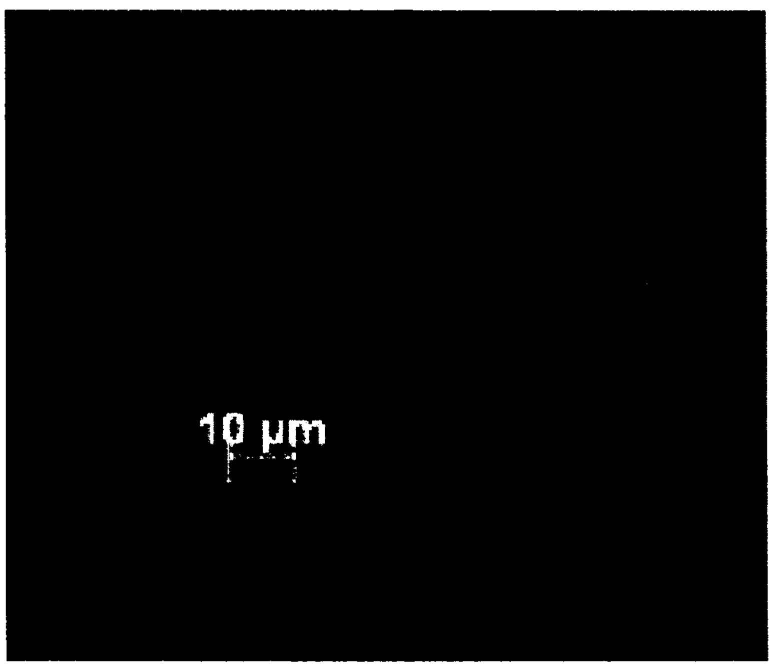

Figure 84.3: Unknown Starch

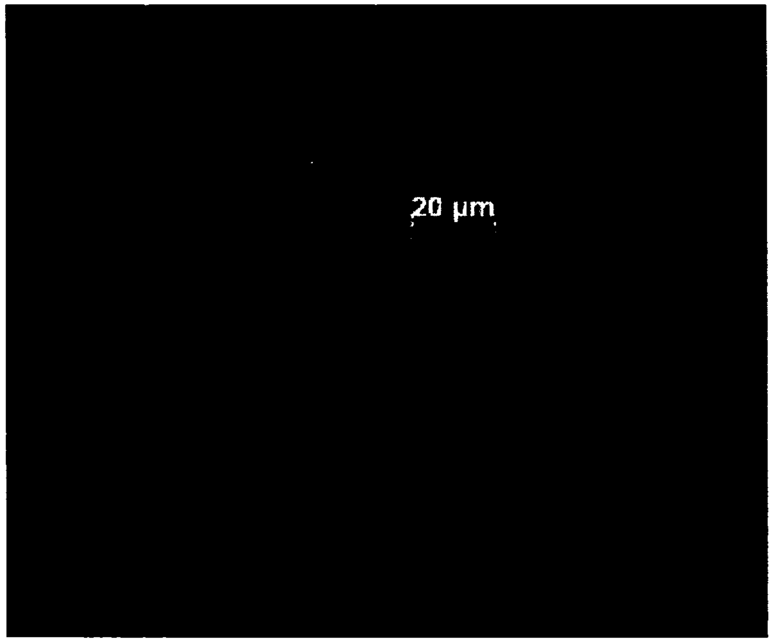

Figure 84.4: Damaged Unknown Bean Starch

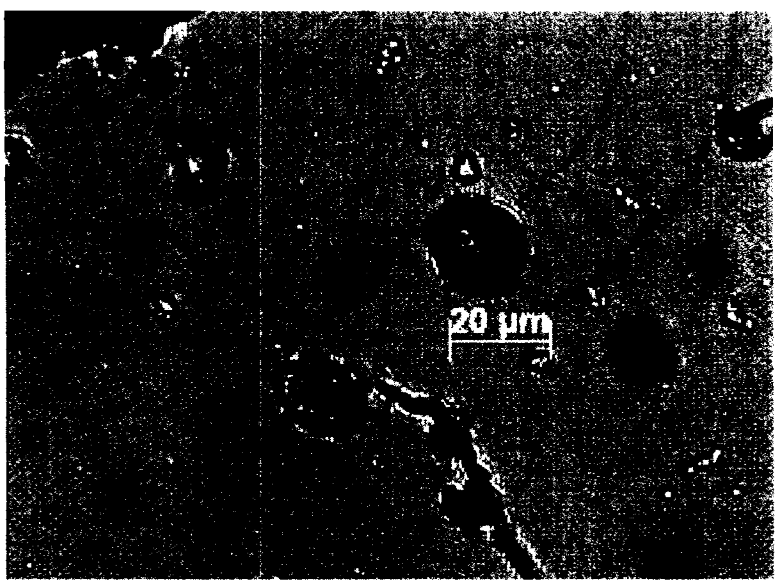

Figure 84.5: Starch from cf. *Sorghum*

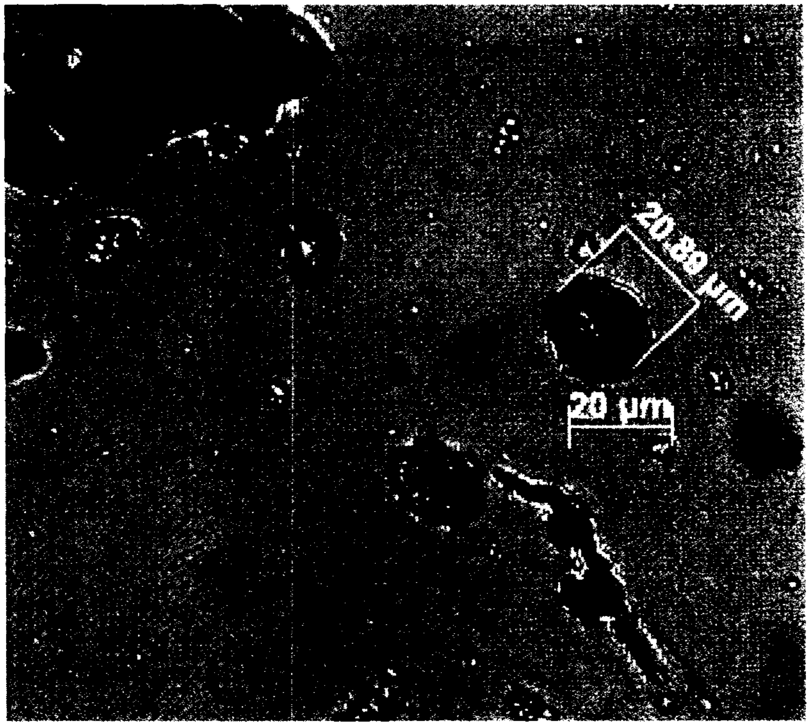

Figure 84.5: Starch from cf. *Sorghum*

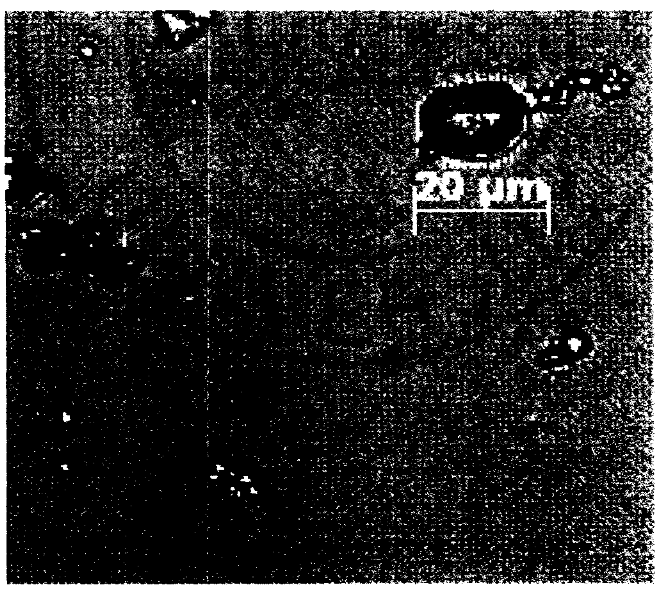

Figure 85.1: Damaged Seed Starch

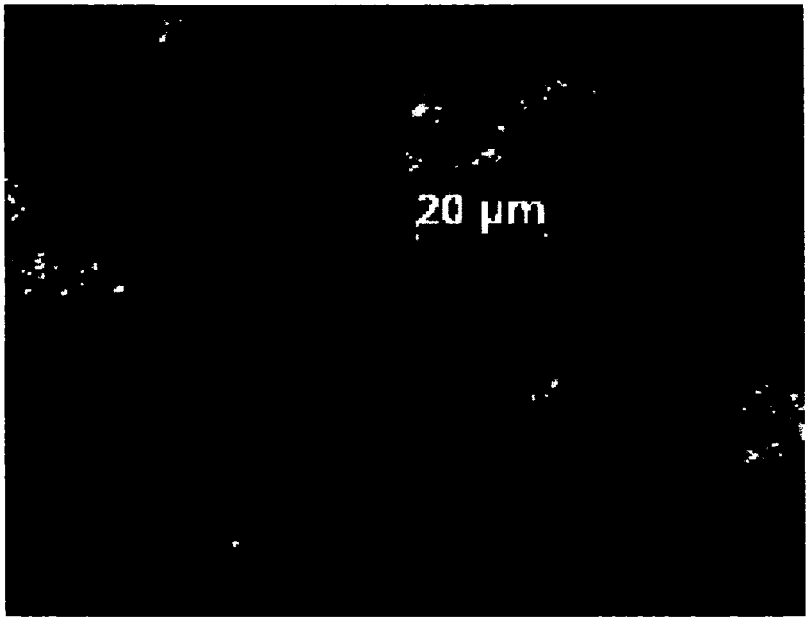

Figure 85.2: Damaged Seed Starch (under polarize light)

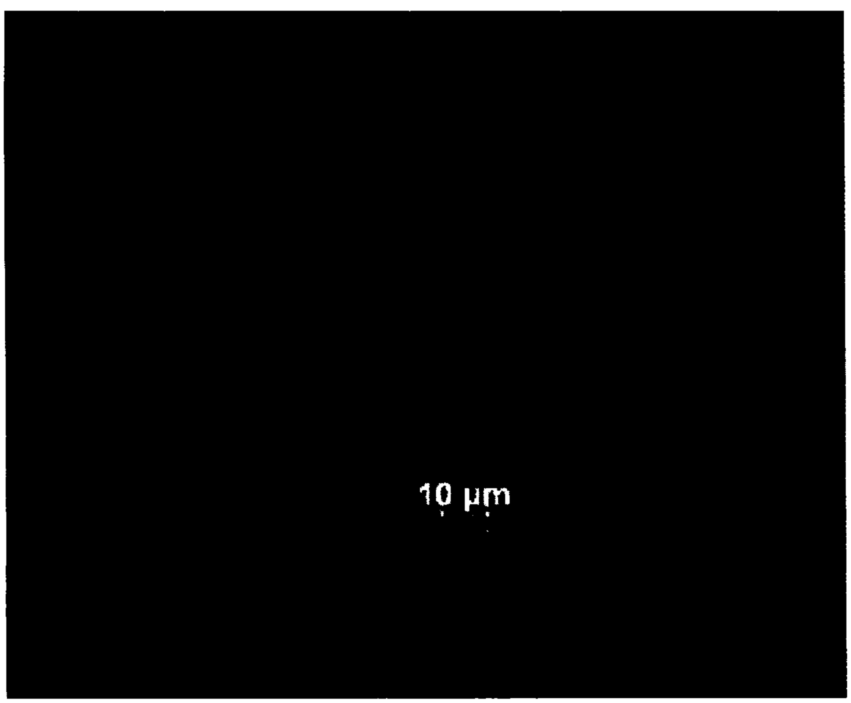

Figure 85.3: Compound Starch

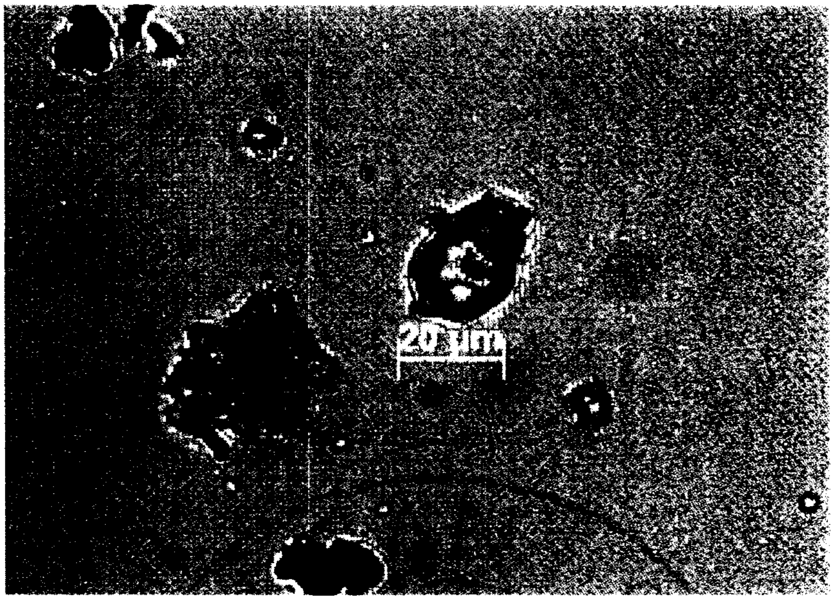

Figure 85.4: Damaged Starch 1

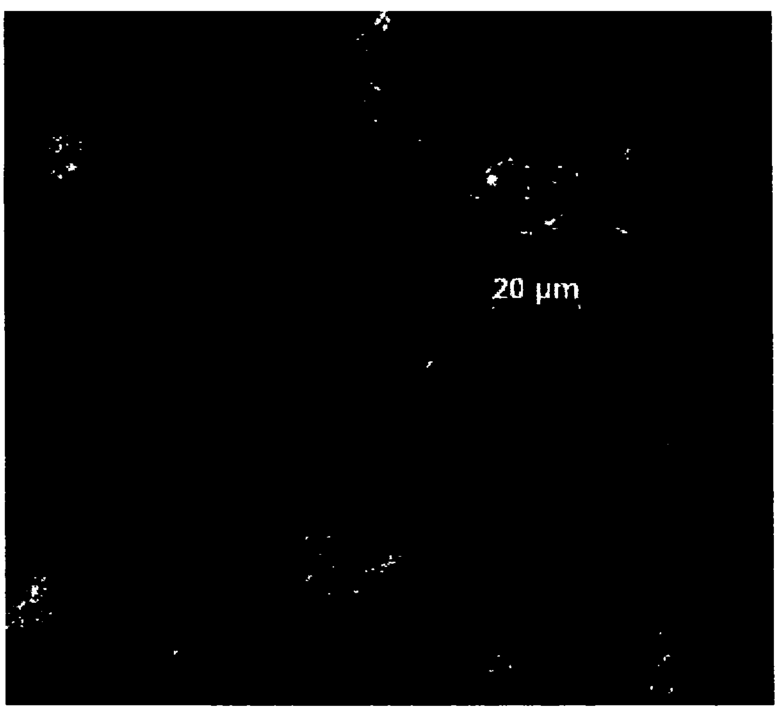

Figure 85.5: Damaged Starch 1 (under polarize light)

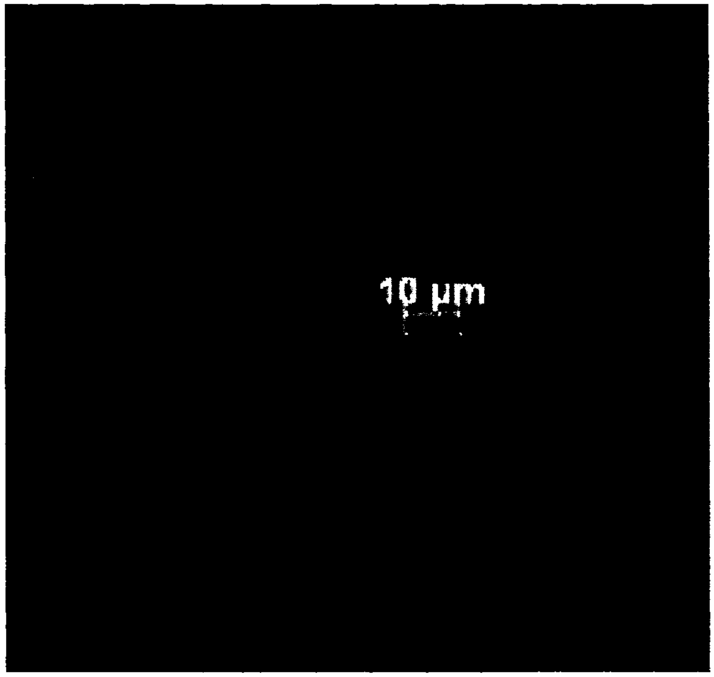

Figure 85.6: Compound Starch

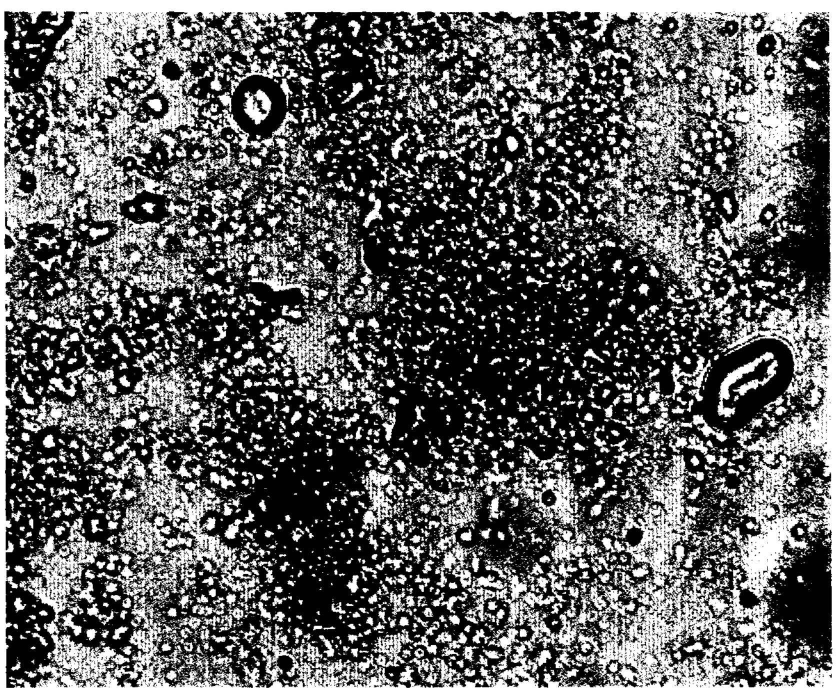

Figure 86.1: Elongate and Spherical Starches from cf. *Vigna* sp.

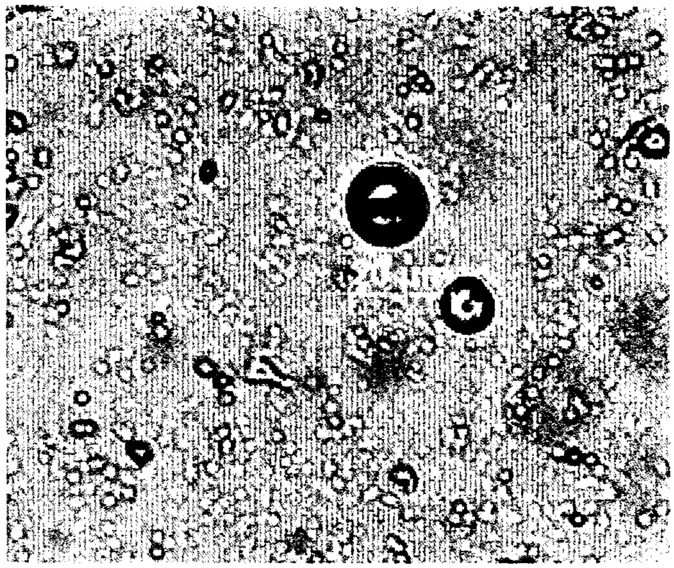

Figure 86.2: Spherical Starches from cf. *Vigna* sp

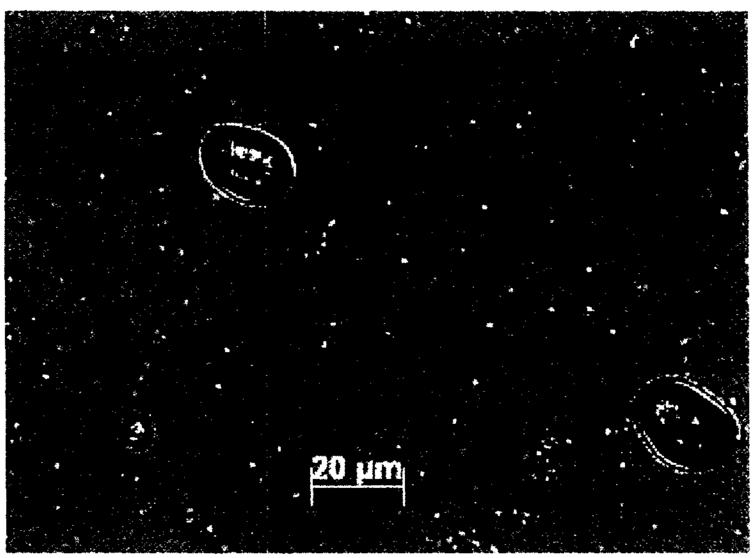

Figure 86.3: Elongate Starches from cf. *Vigna* sp.

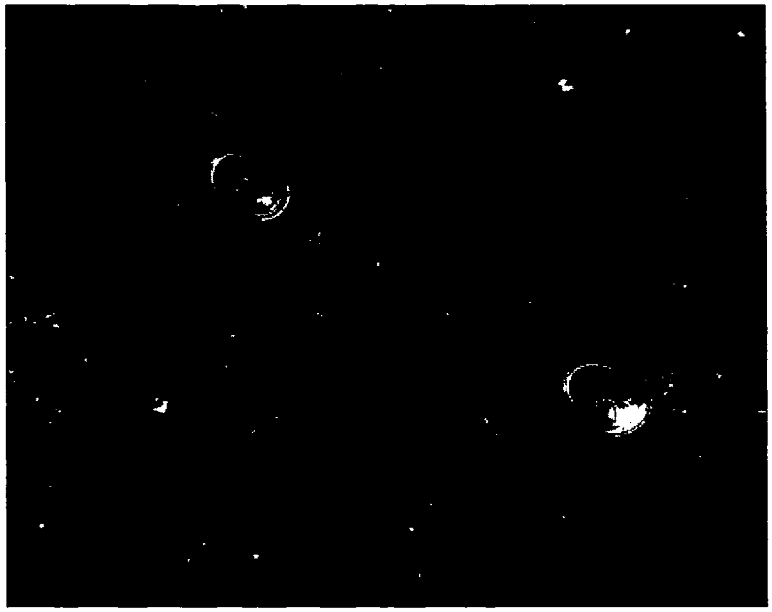

Figure 86.4: Elongate Starches from cf. *Vigna* sp (under polarize light)

Figure 86.5: Elongate Starch from cf. Vigna sp.

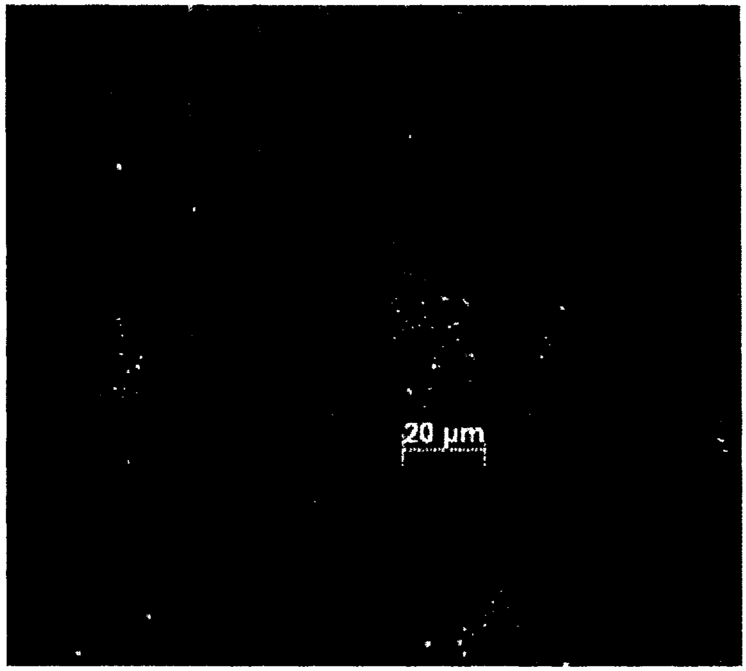

Figure 86.6 Unknown Damages Starch 1

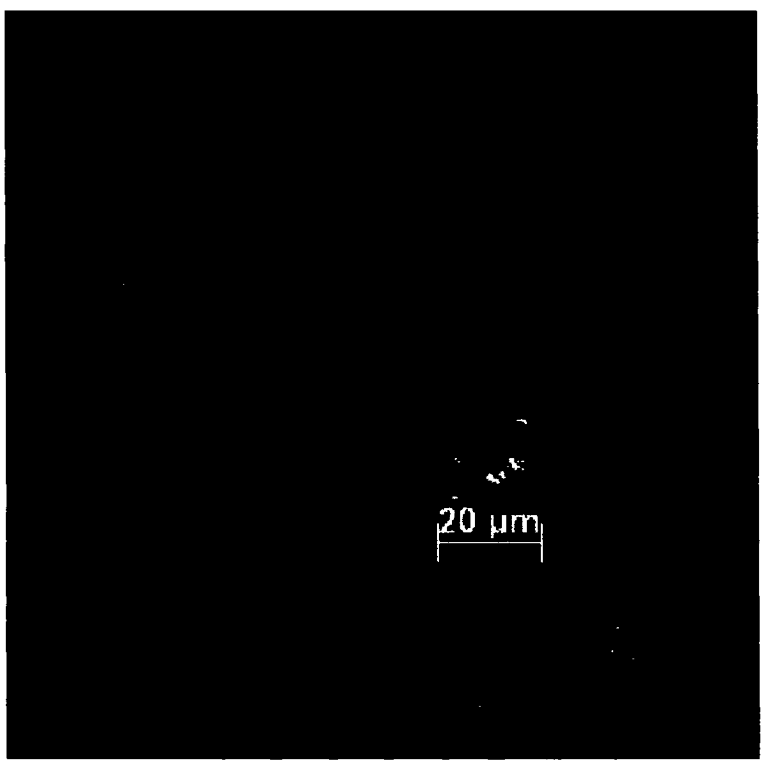

Figure 86.7 Unknown Damages Starch 1 (under polarize light)

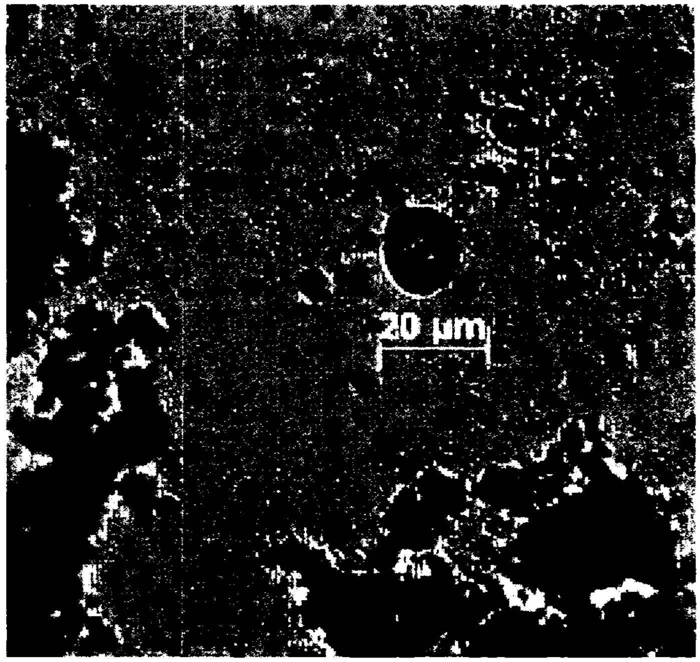

Figure 86.8 Unknown Damages Starch 2

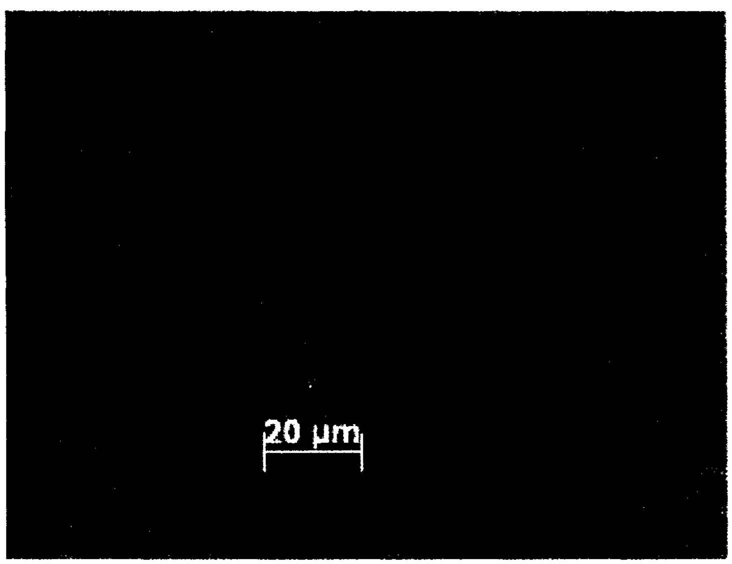

Figure 86.9 Compound Starch

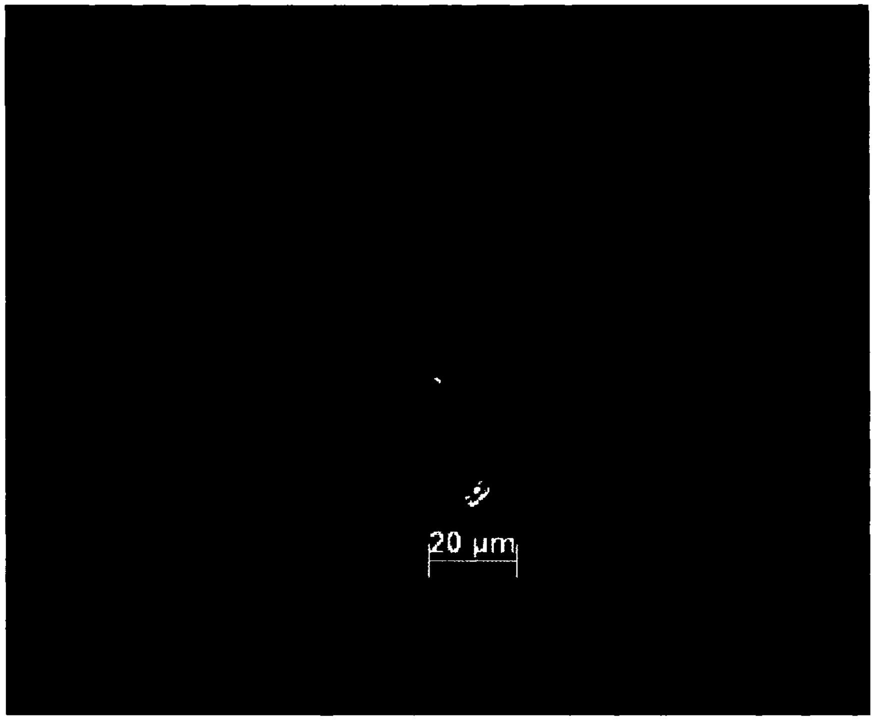

Figure 86.10 Compound Starch 1

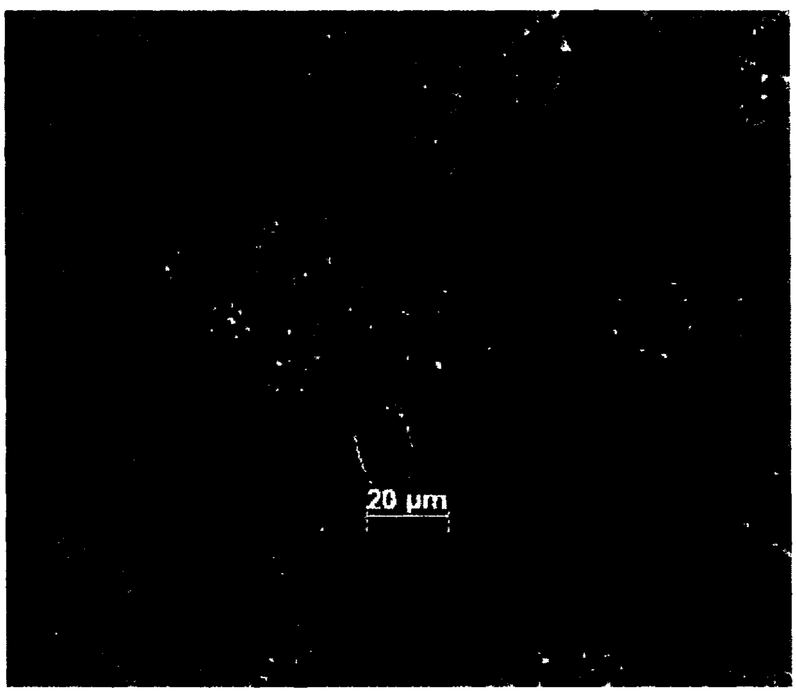

Figure 86.11 Starch from cf. *Phoenix*

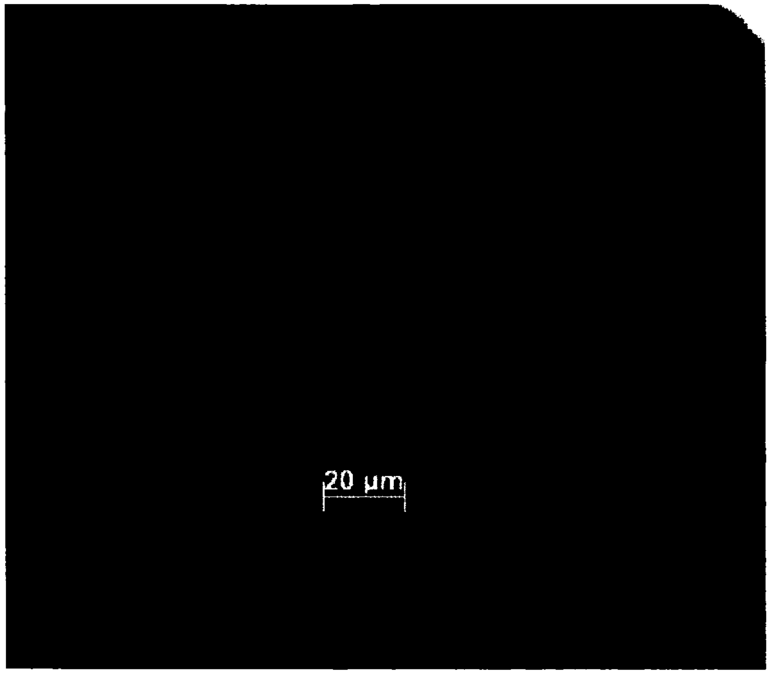

Figure 86.12 Ground up Seed Starch

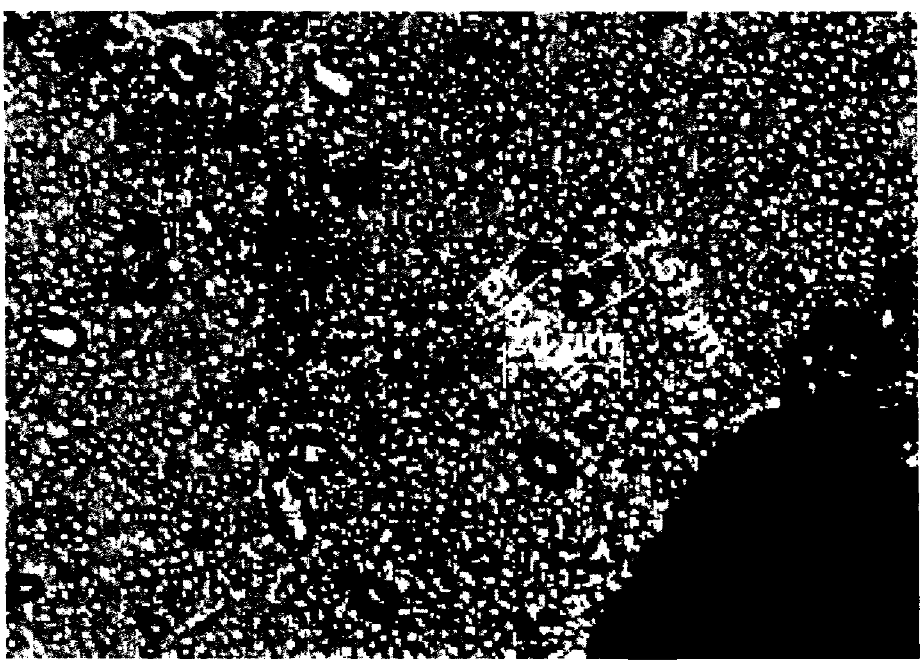

Figure 86.13 Starches from cf. *Sesamum* (measurement)

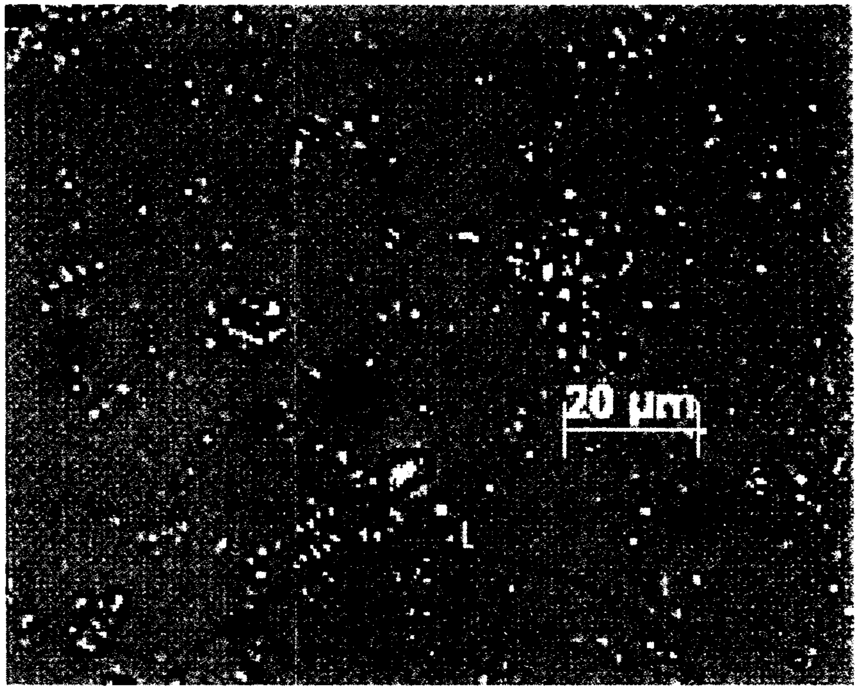

Figure 86.14: Starches from cf. *Sesamum*

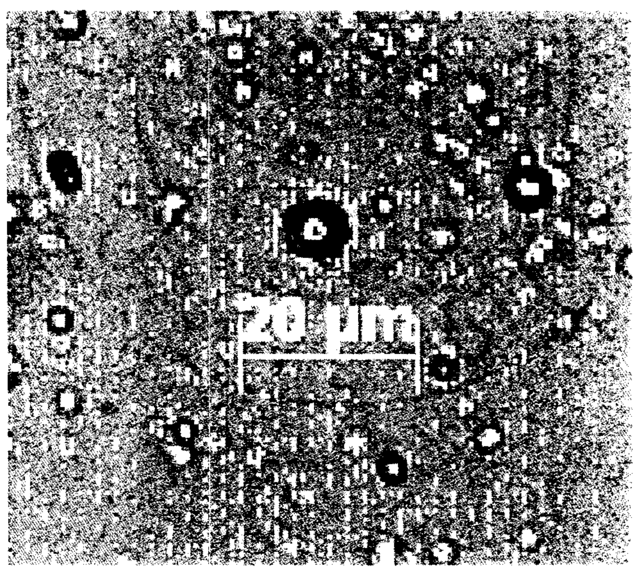

Figure 86.15: Starch from cf. *Sesamum*

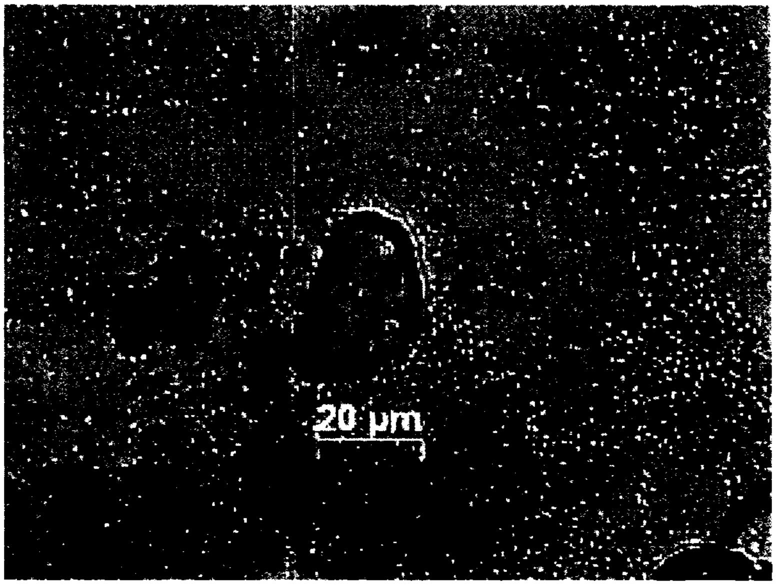

Figure 86.16: Unknown Starch

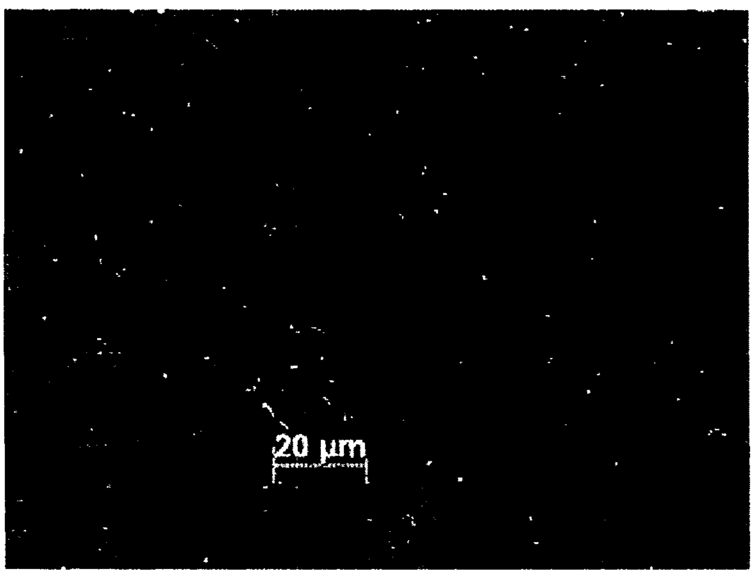

Figure 86.17: Ground up Starch from seed

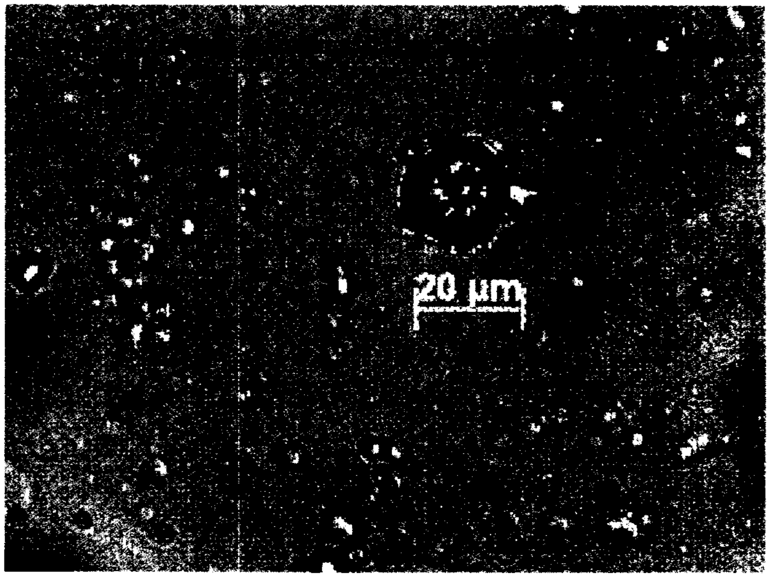

Figure 86.18: Spherical Starch from cf. *Vigna* (urid)

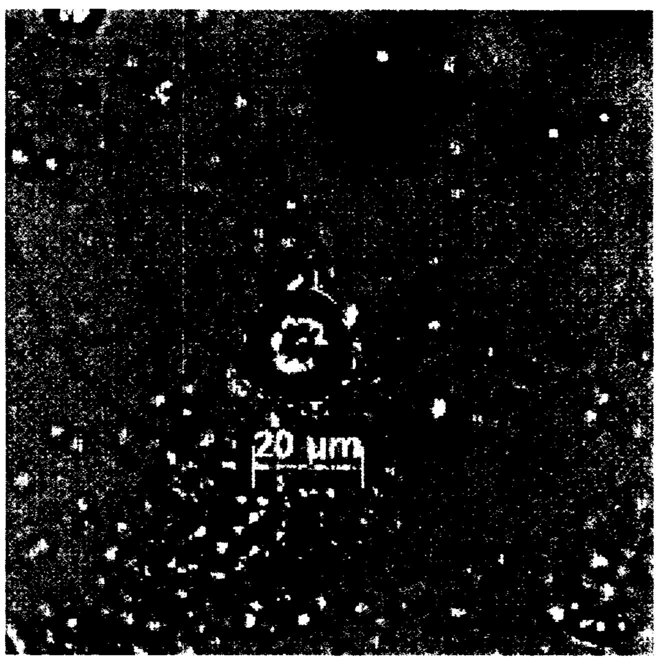

Figure 86.19: Spherical Starch from cf. *Vigna* (urid)

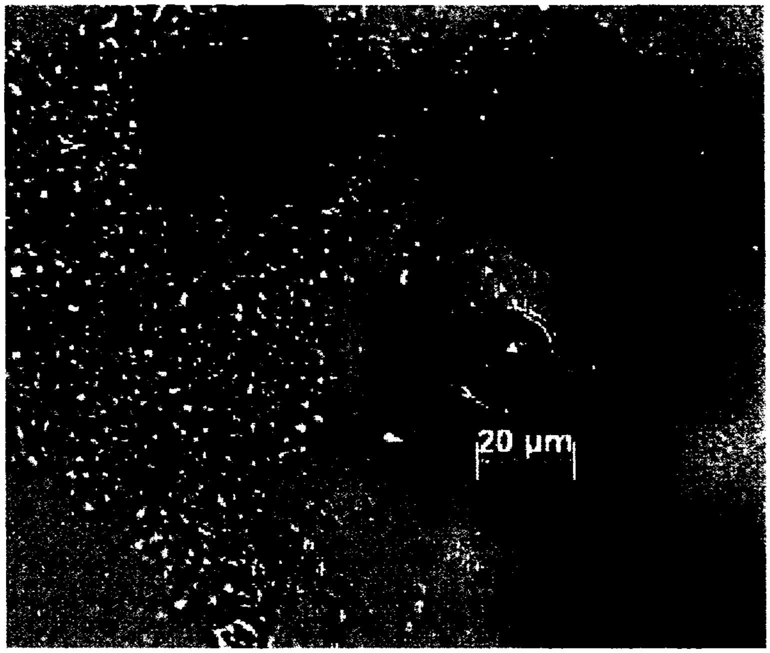

Figure 86.20: Spherical Starch from cf. *Vigna* (urid)

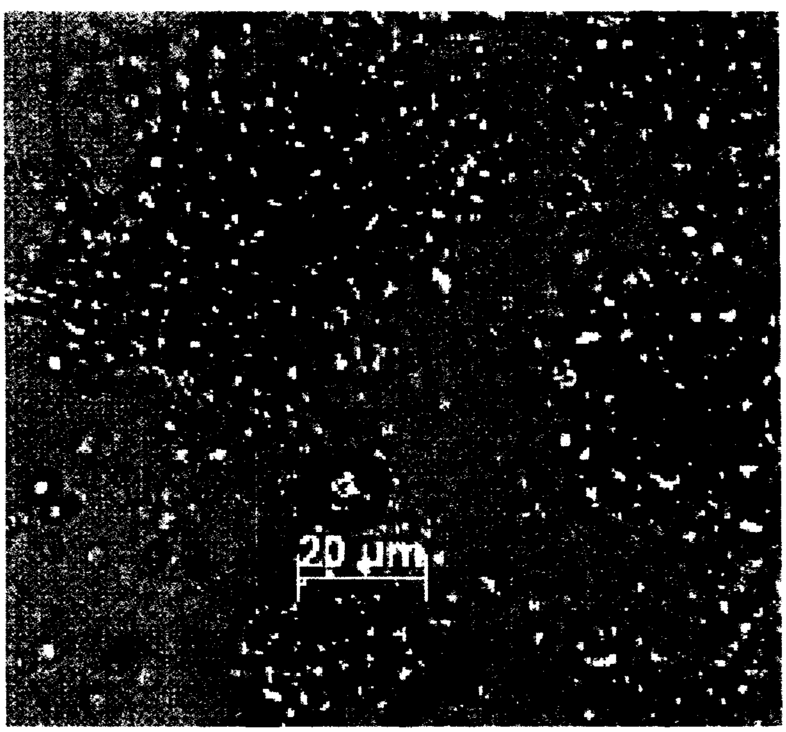

Figure 86.21: Ground up Seed Starch

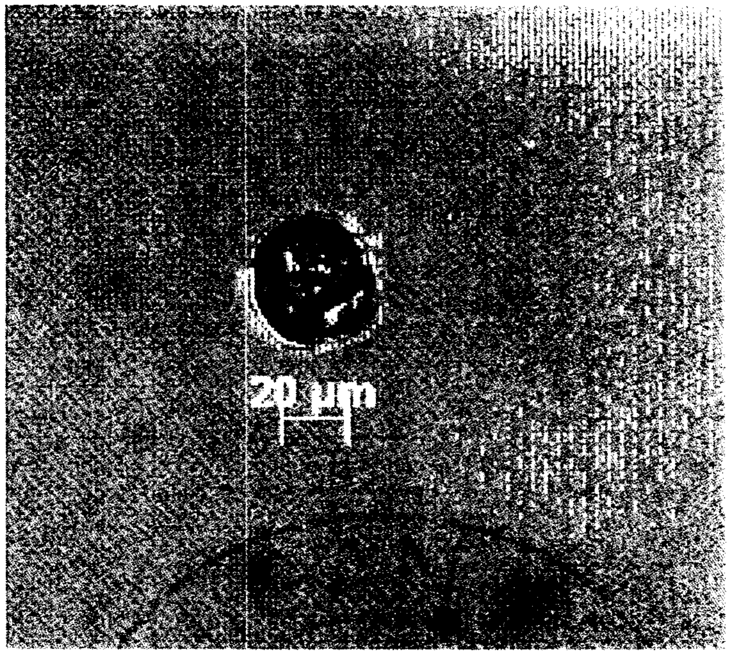

Figure 87.1: Unknown Damaged Starch 1

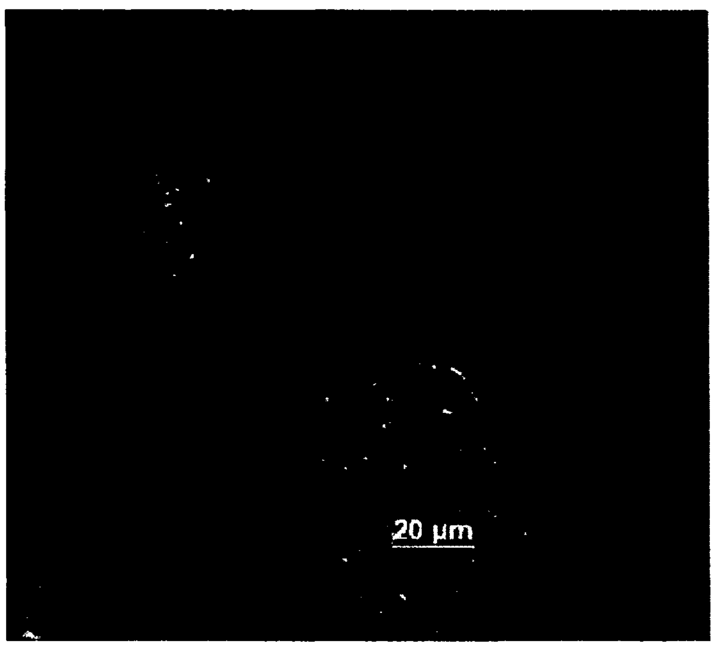

Figure 87.2: Unknown Damaged Starch 2

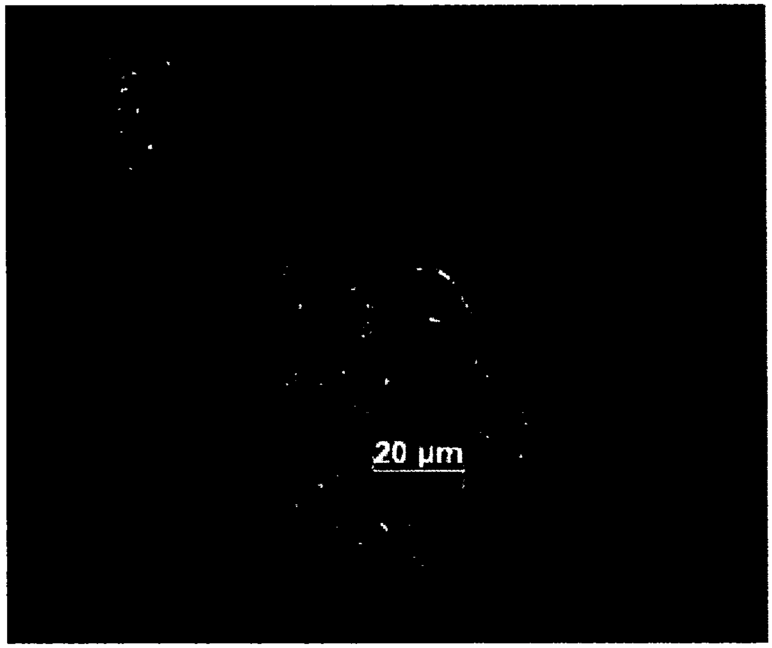

Figure 87.3: Unknown Damaged Starch 2 (measurement)

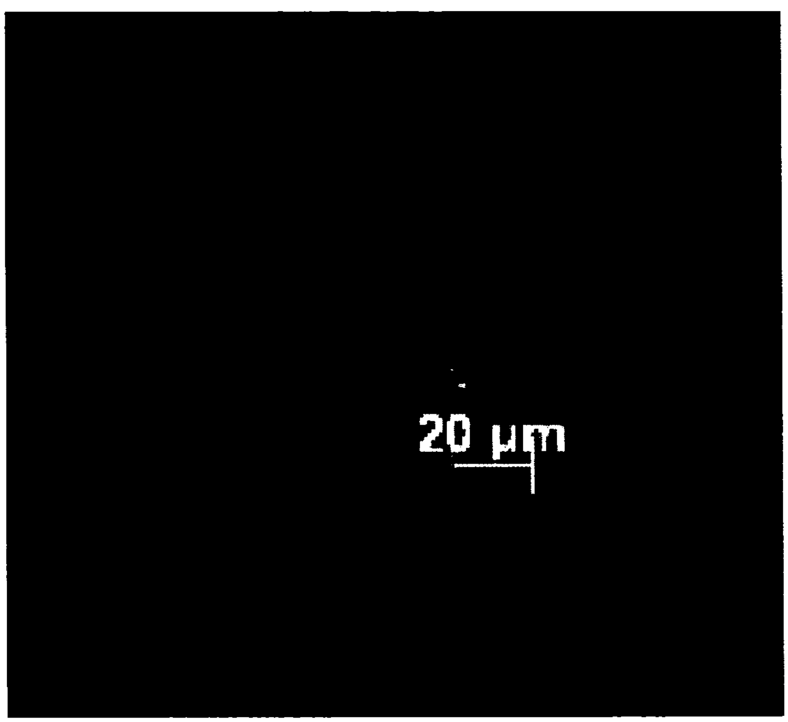

Figure 87.4: Starch from cf. *Eleusine*

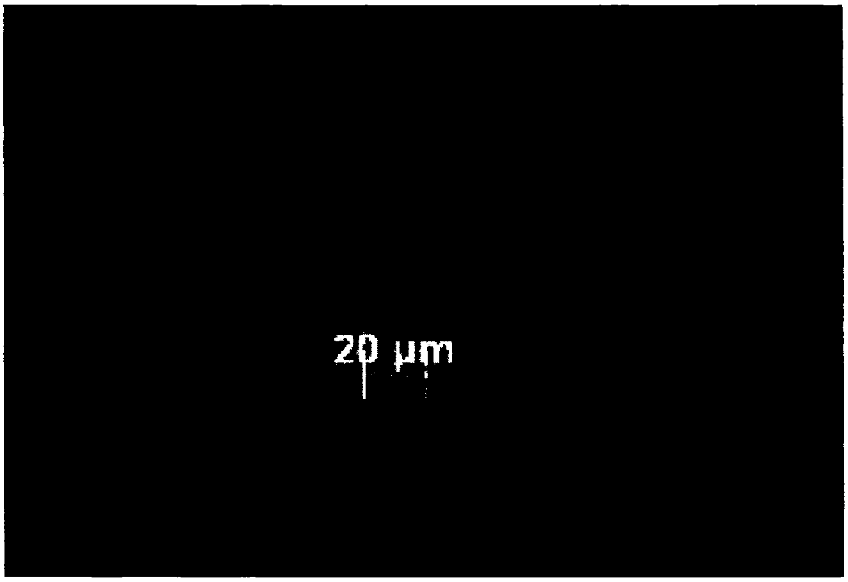

Figure 87.5: Measurement of Starch granules from cf. *Eleusine*

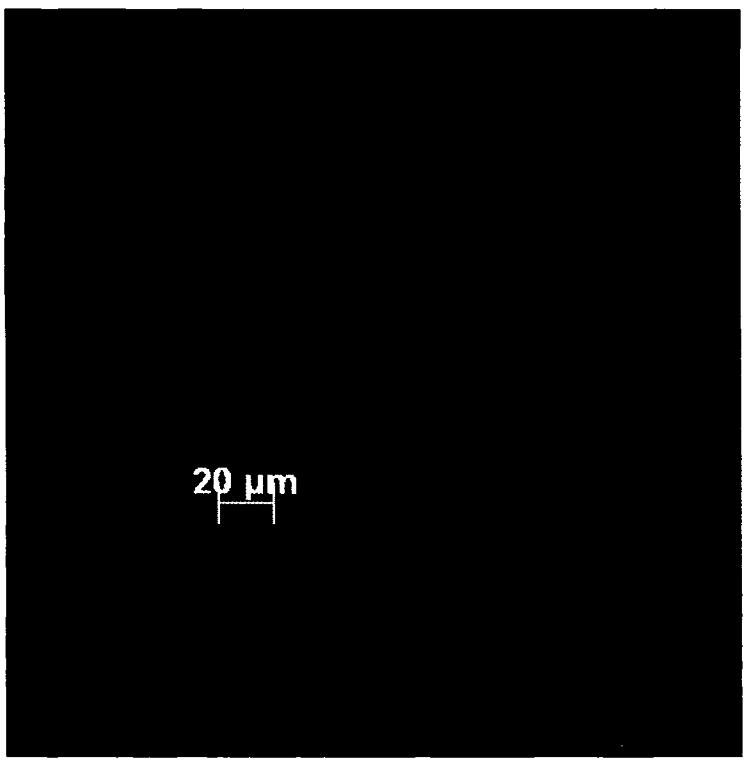

Figure 87.6: Bell Shaped Starch from Seed of cf. *Solanum*

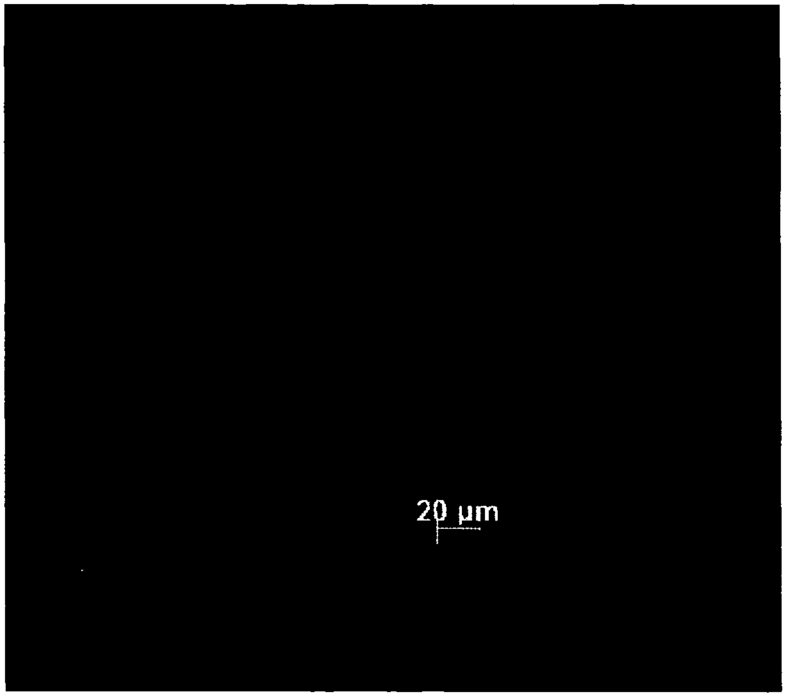

Figure 87.7: Bell Shaped Starch from Seed of cf. *Solanum* (measure)

Figure 87.8: Bell Shaped Starch from Seed of cf. *Solanum*

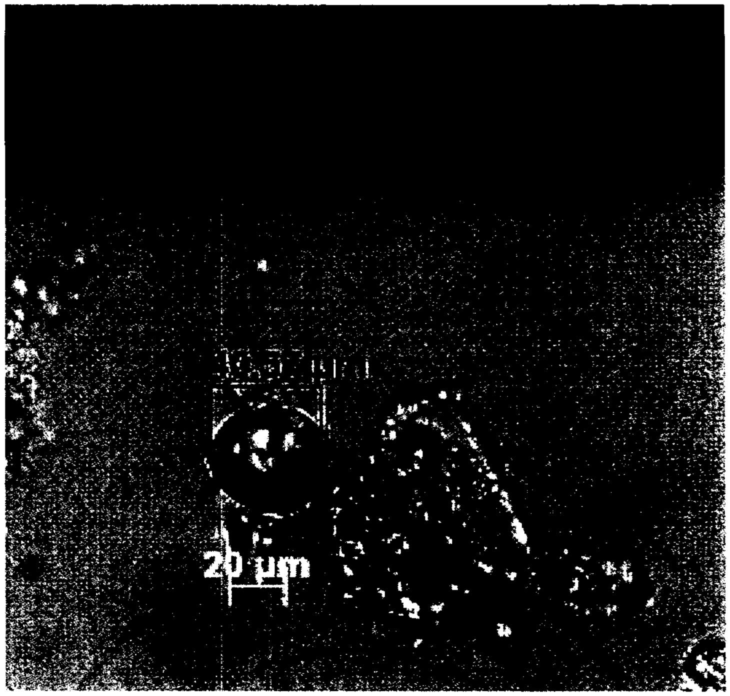

Figure 87.9: Bell Shaped Starch from Seed cf. *Solanum* (measurement)

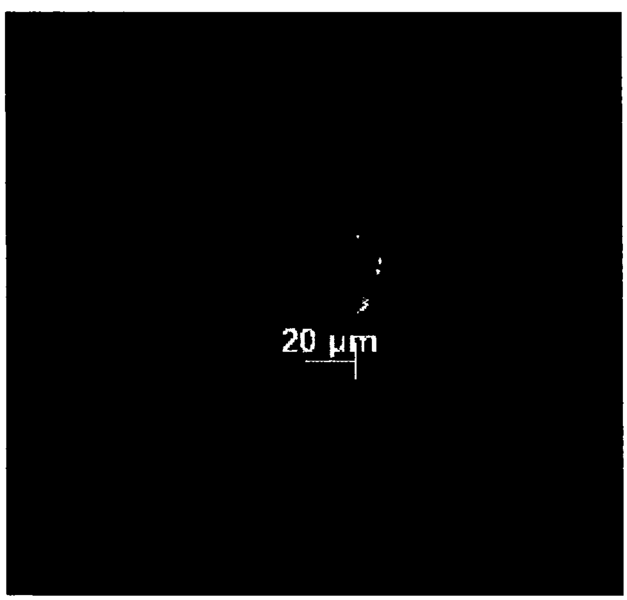

Figure 87.10: Starch consistent Seed of cf. *Solanum* (under polarize light)

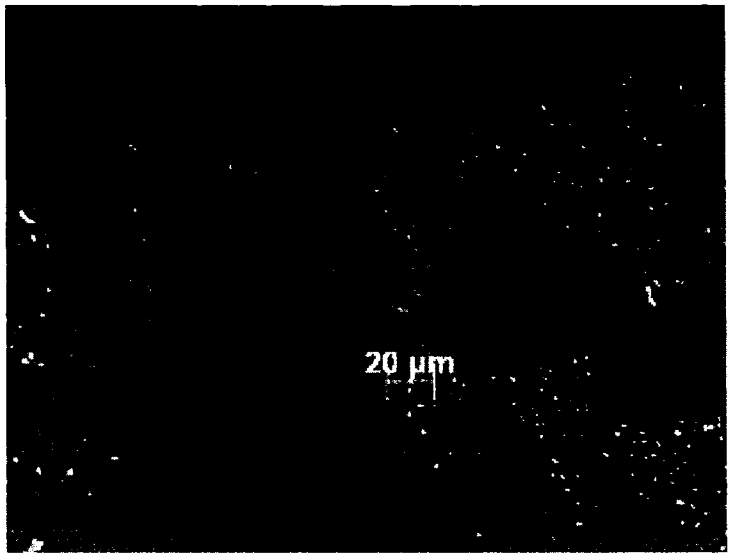

Figure 87.11: Starch from cf. *Solanum*

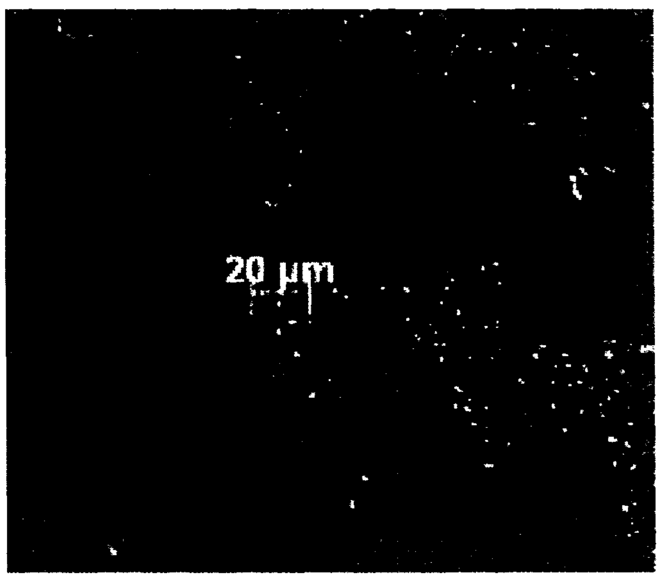

Figure 87.12: Starch from cf. cf. *Solanum* (measure)

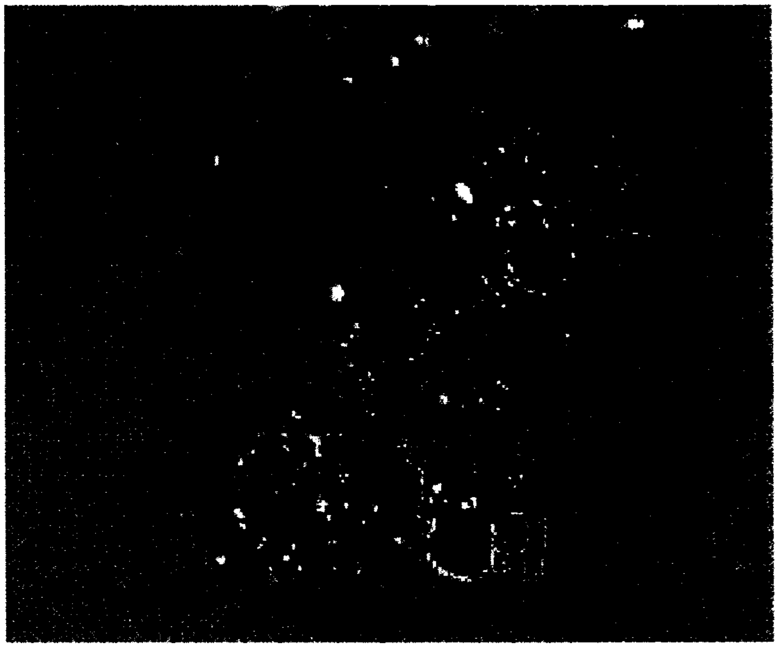

Figure 87.13: Spherical Starch from Seed of cf. *Solanum* (measurement)

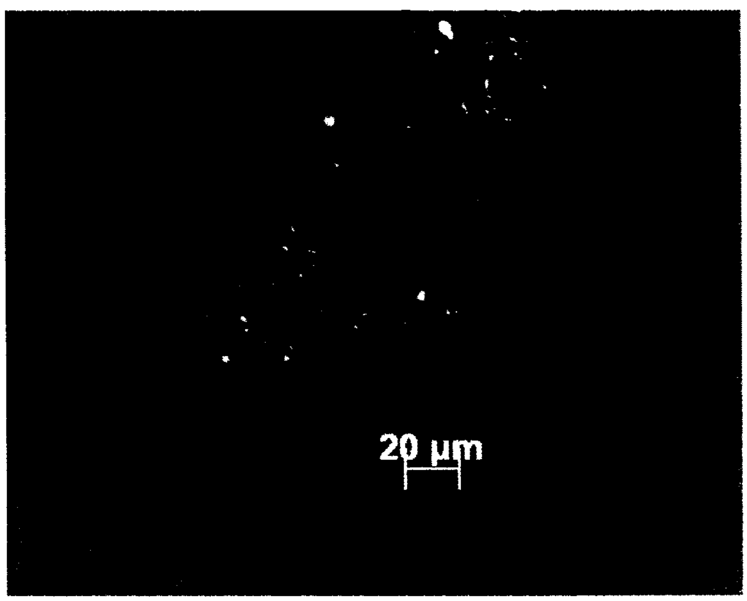

Figure 87.14: Spherical Starch from cf. *Solanum*

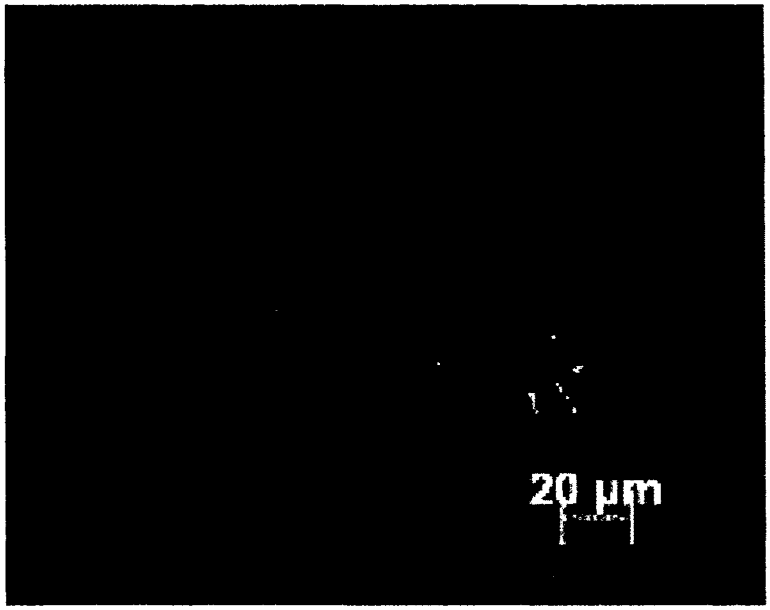

Figure 87.15: Damaged Starch from cf. *Solanum*

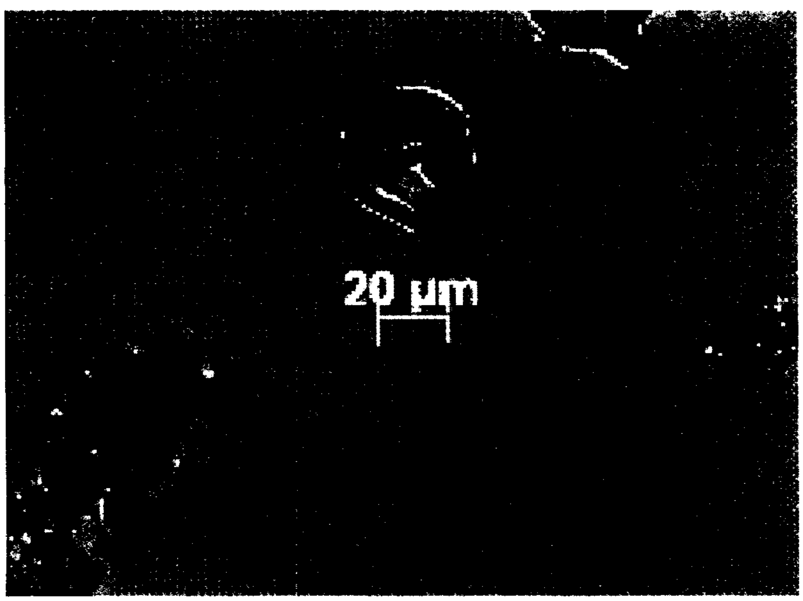

Figure 87.16: Starch from Seed of cf. *Solanum*

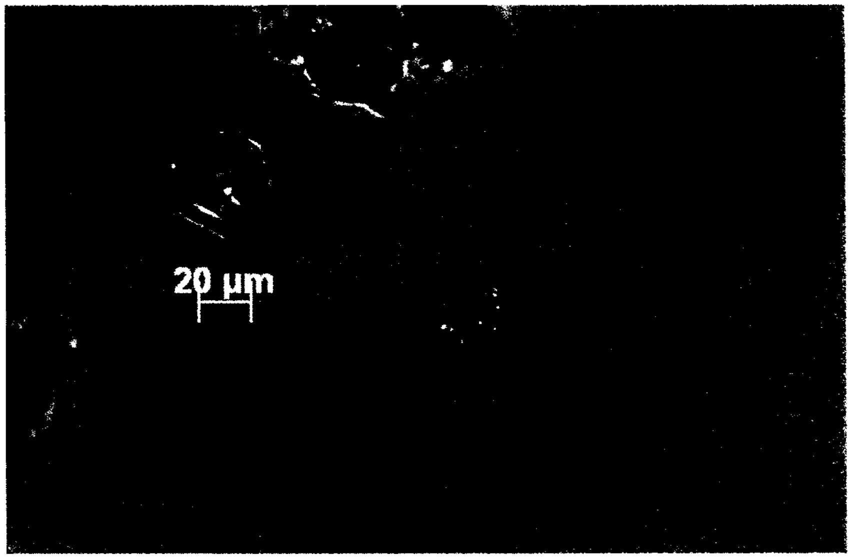

Figure 87.17: Starch from Seed of cf. *Solanum*

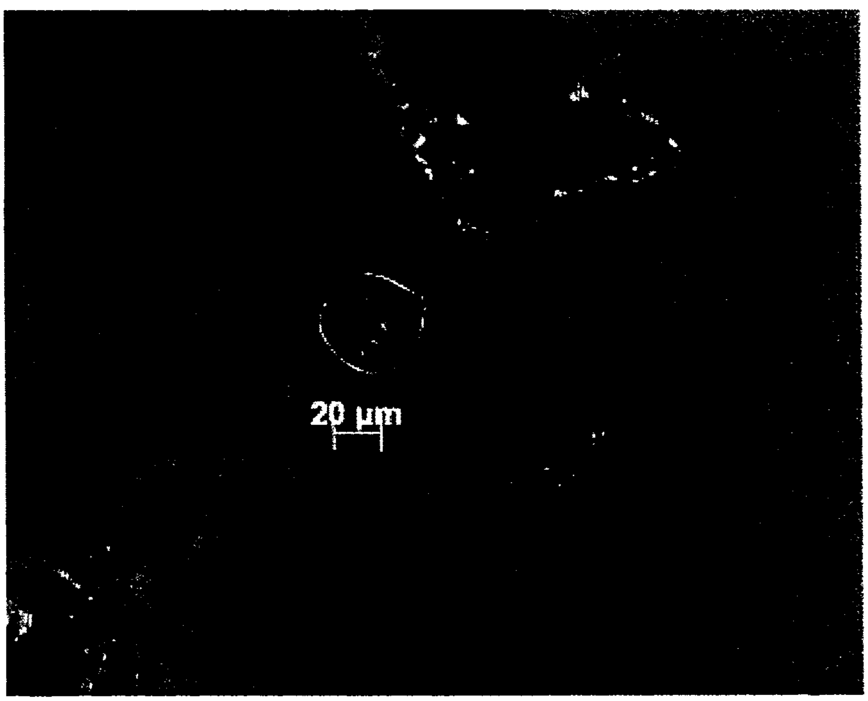

Figure 87.18: Damaged Starch from Seed of cf. *Solanum*

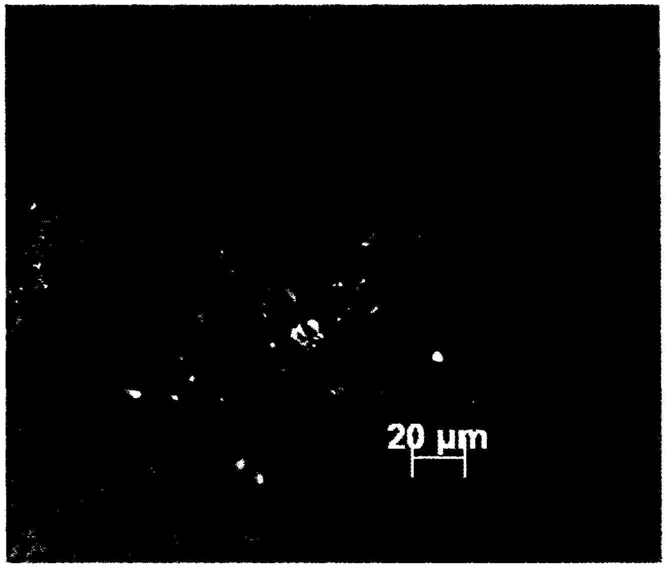

Figure 87.19: Starch of cf. *Sorghum*

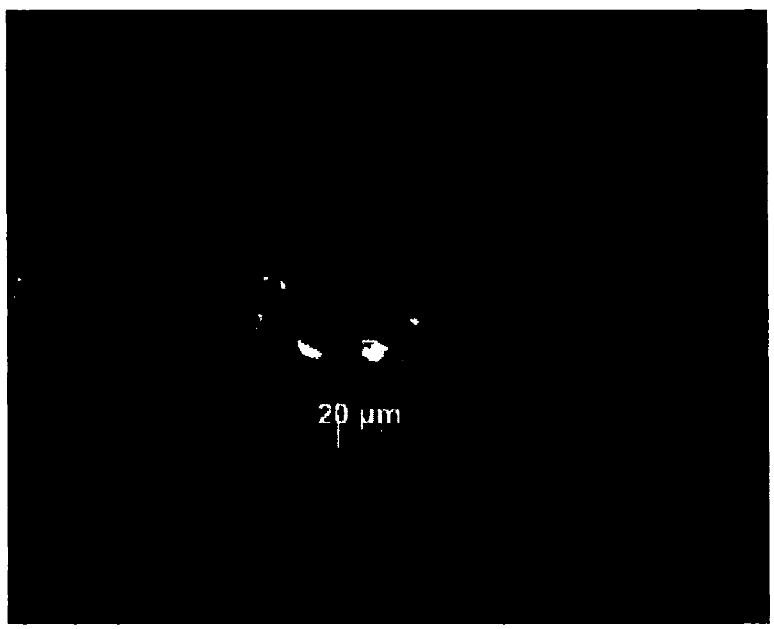

Figure 87.20: Starch of cf. *Sorghum* (under polarize light)

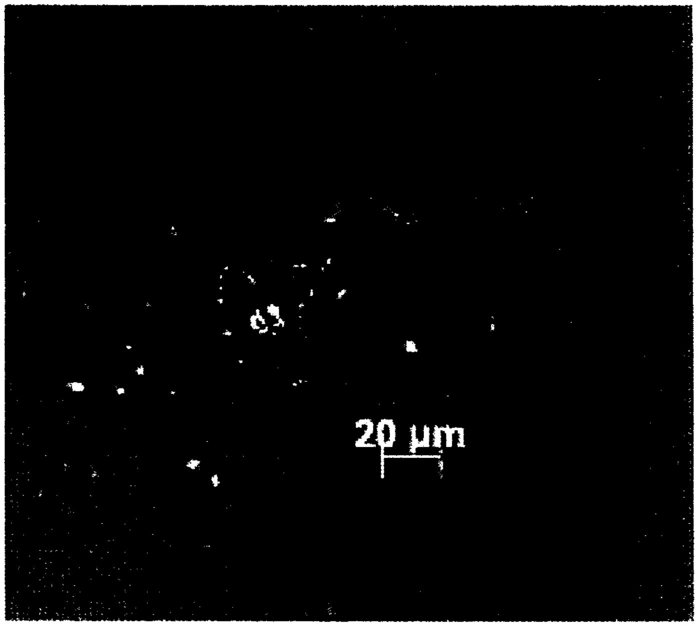

Figure 87.21: Starch cf. *Sorghum* (measurement)

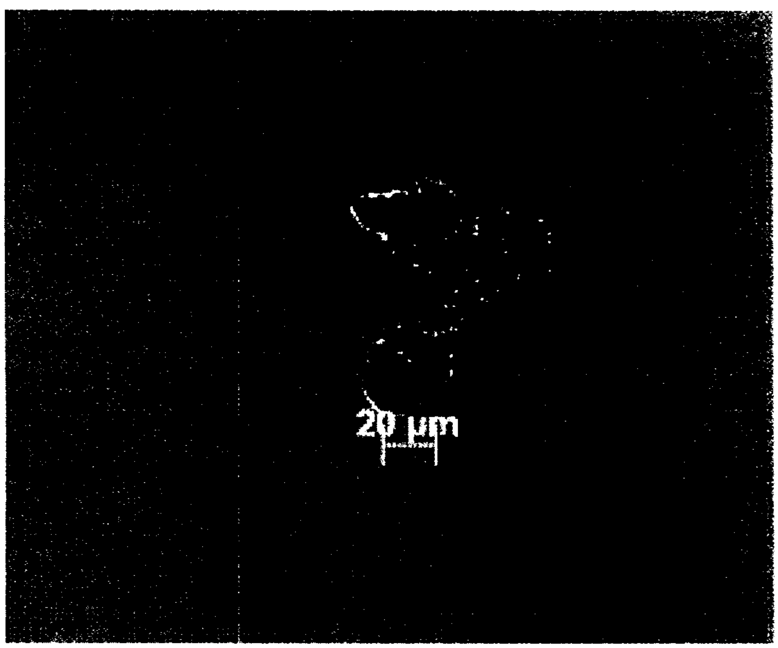

Figure 87.22: Starch from Seed of cf. *Solanum*

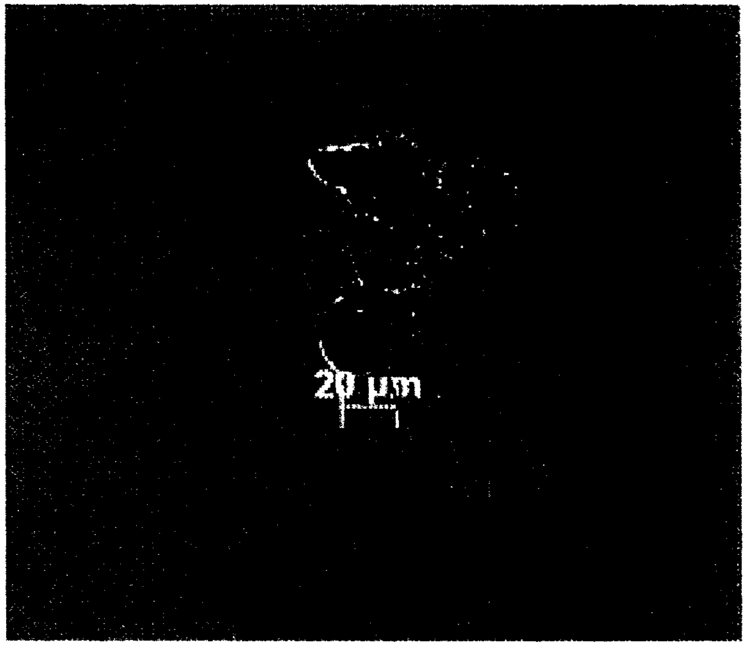

Figure 87.23: Starch from Seed of cf. *Solanum*

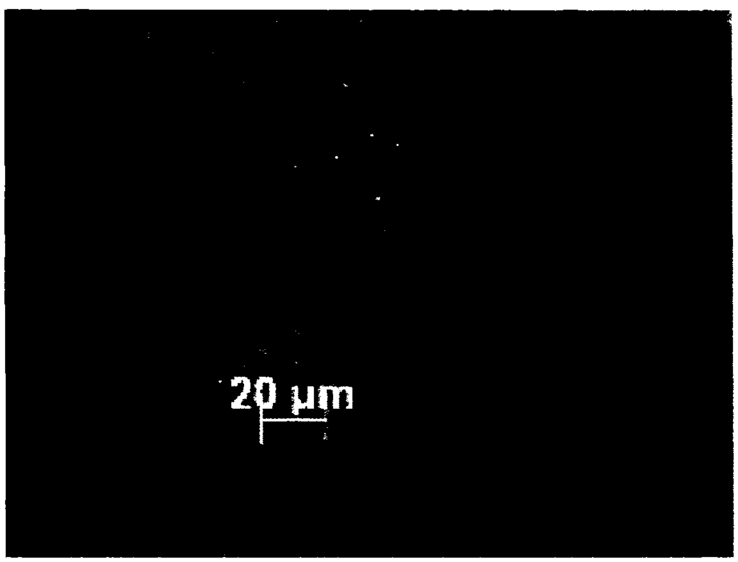

Figure 87.24: Starch from Seed of cf. *Solanum*

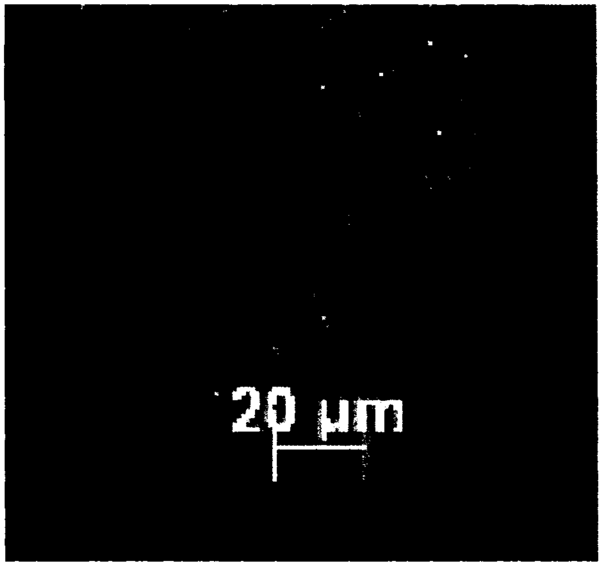

Figure 87.25: Starch from Seed of cf. *Solanum* (measurement)

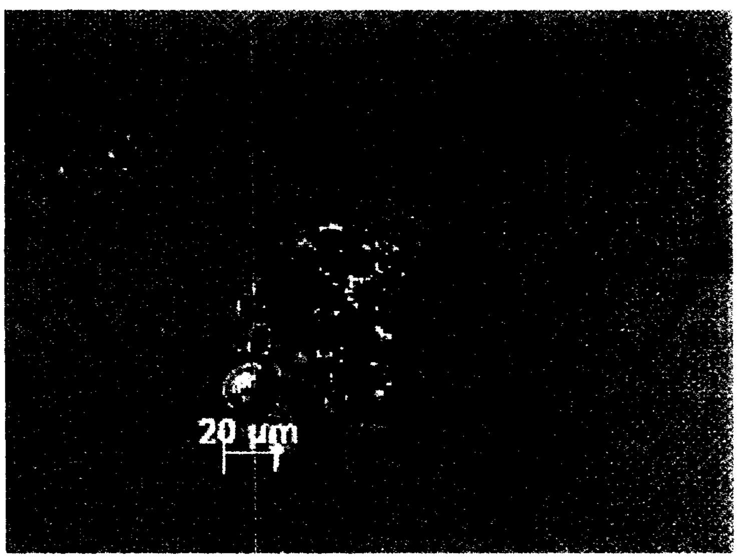

Figure 87.26: Unknown Starch 1

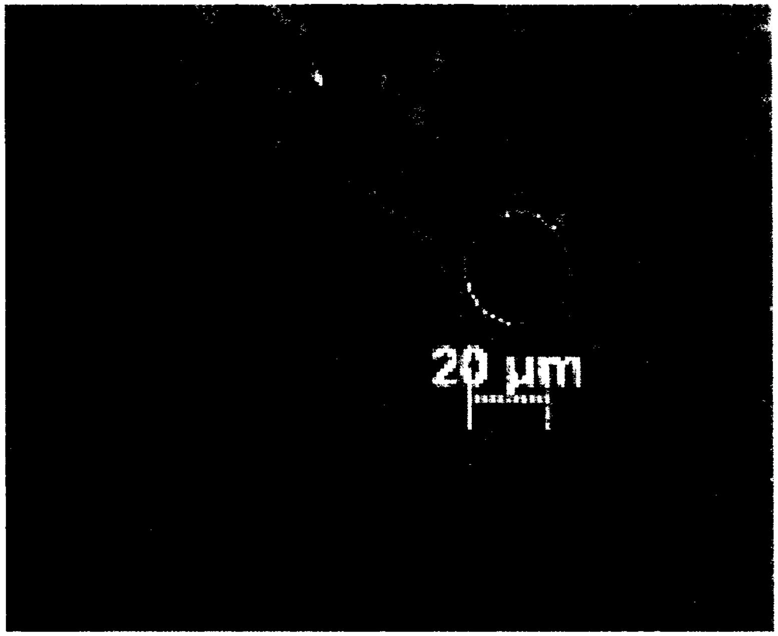

Figure 87.27: Unknown Starch 1 (on rotation)

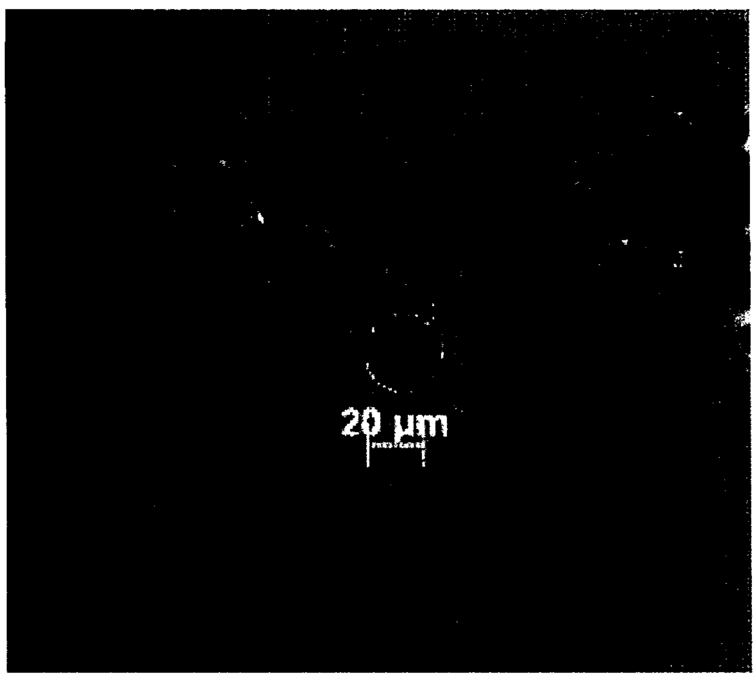

Figure 87.28: Unknown Starch 1 (measurement)

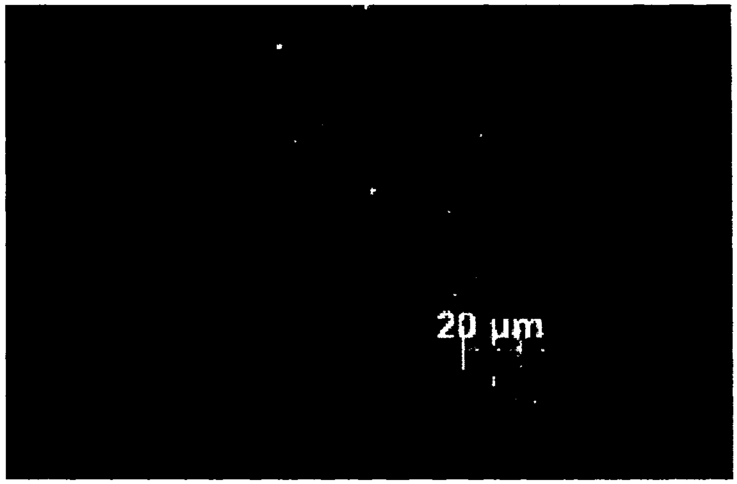

Figure 87.29: Starch from pericarp of cf. *Solanum*

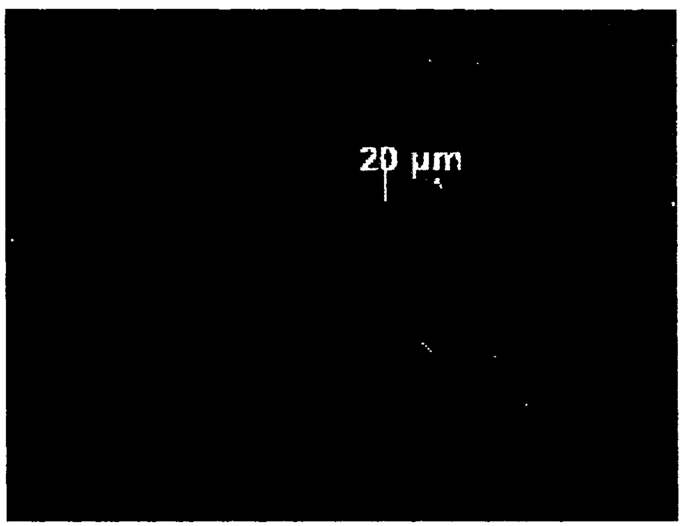

Figure 87.30: Starch from pericarp of cf. *Solanum*

Figure 87.31: Damaged Starch from cf. *Solanum*

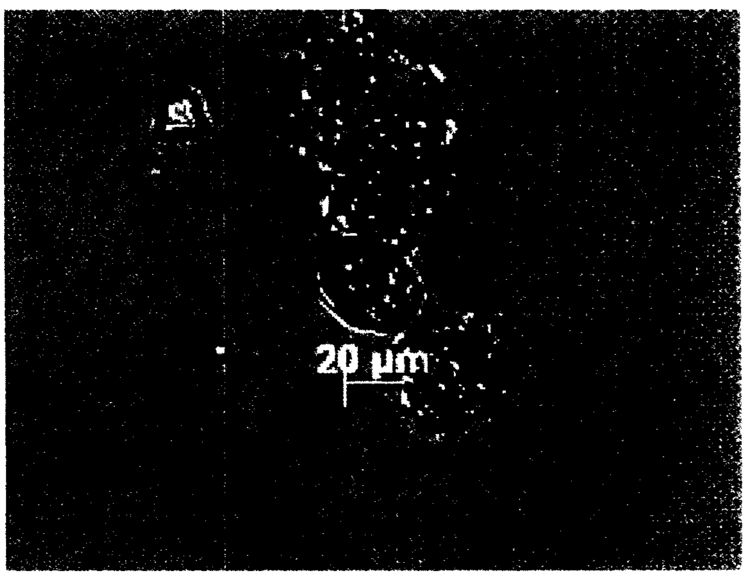

Figure 87.32: Damaged Starch from cf. *Solanum*

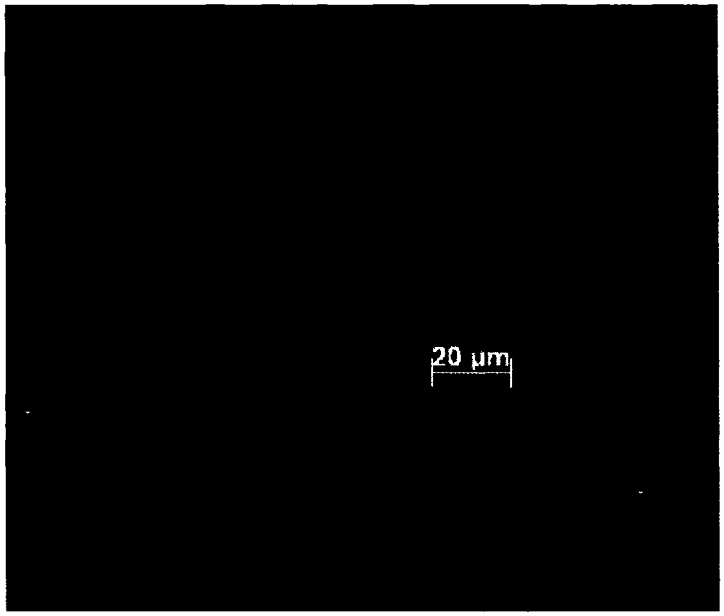

Figure 87.33: Starch from Seed of cf. *Solanum*

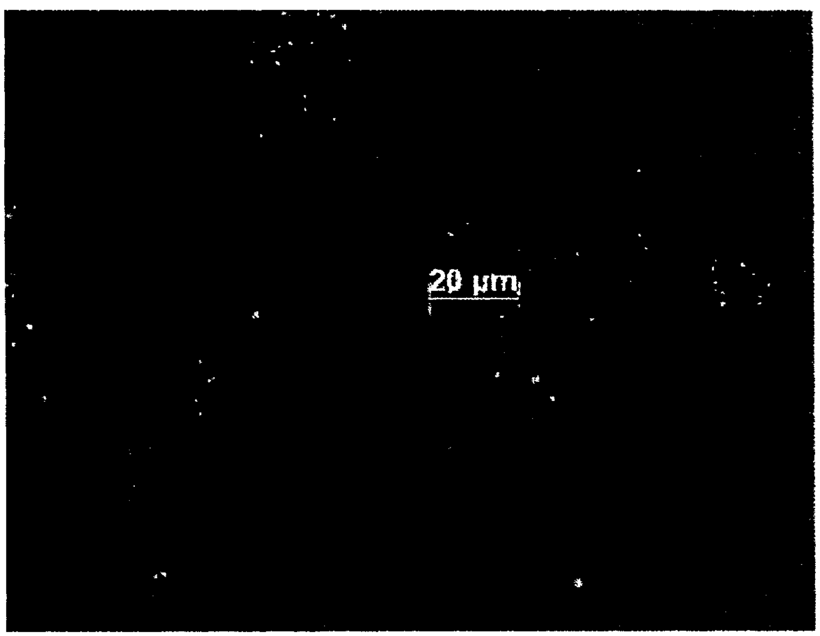

Figure 87.34: Unknown Damaged Starch 8

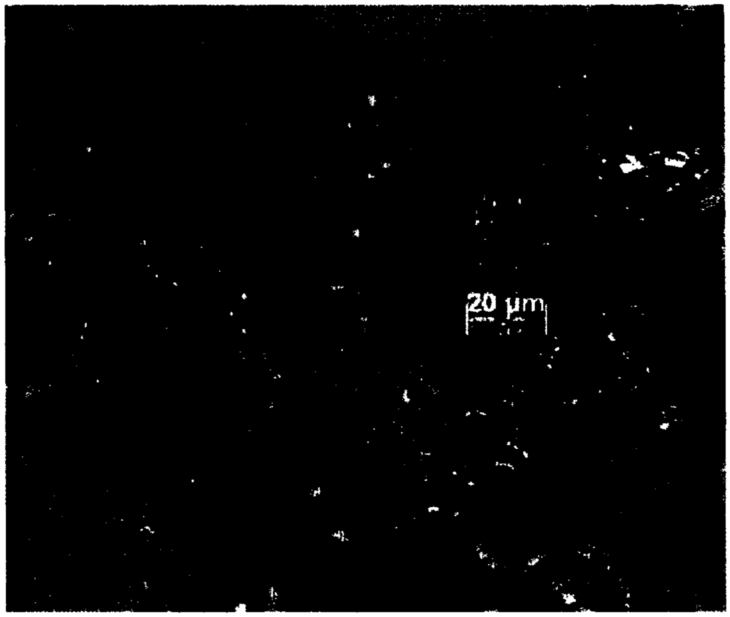

Figure 87.35: Starch from Seed of cf. *Solanum*

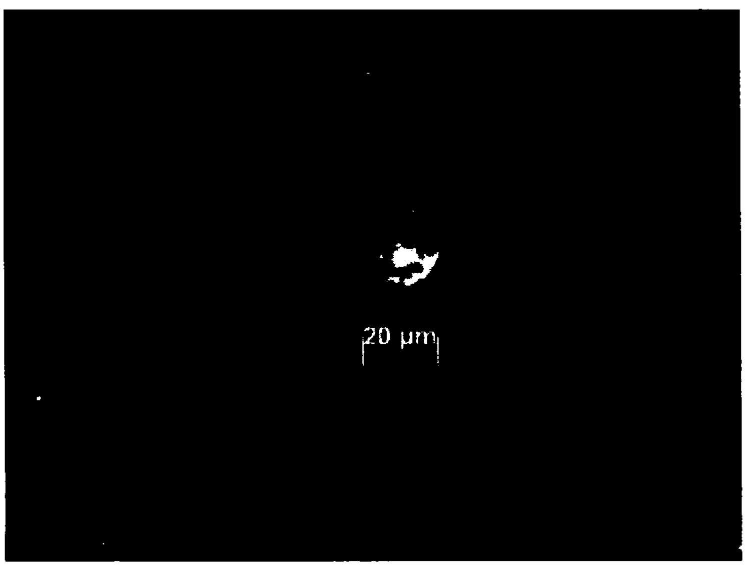

Figure 87.36: Starch from Seed of cf. *Solanum* (under polarize light)

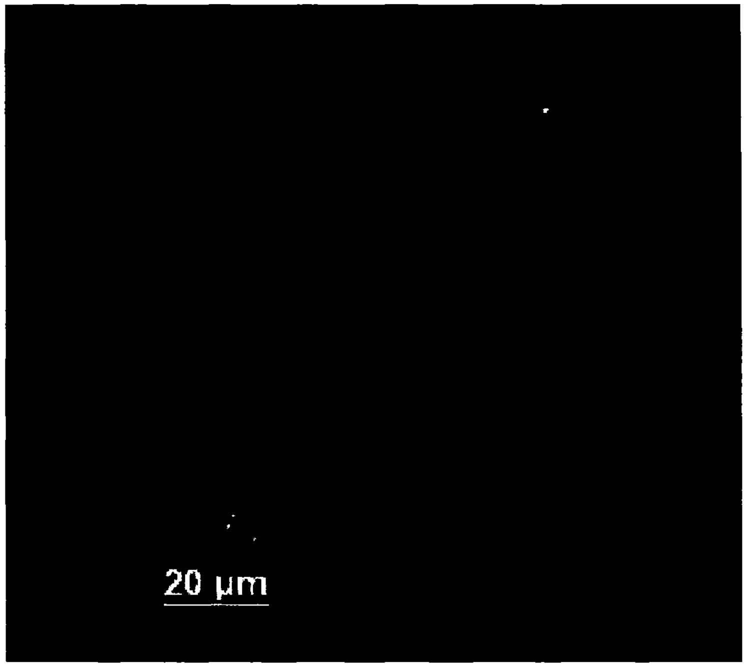

Figure 87.37: Starch from Seed of cf. *Solanum* (under polarize light)

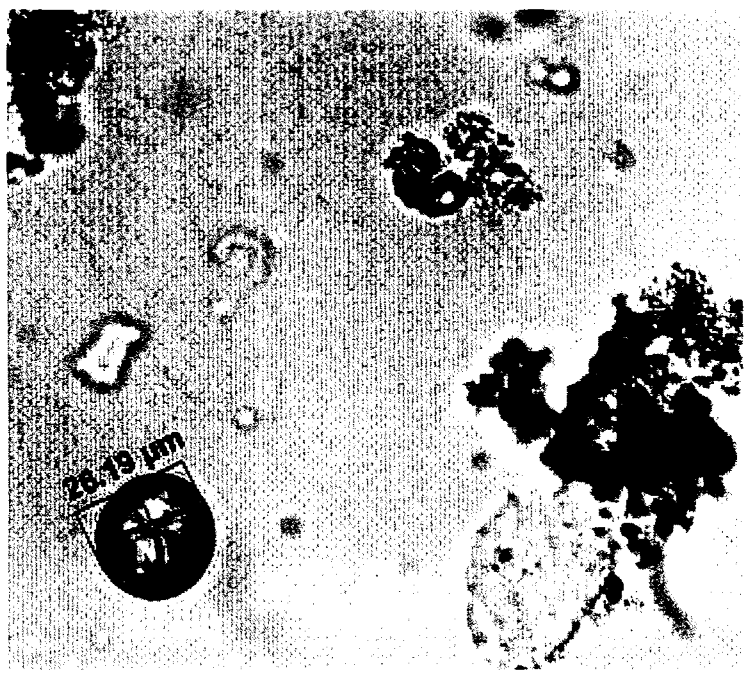

Figure 87.38: Starch from Seed of cf. *Solanum*

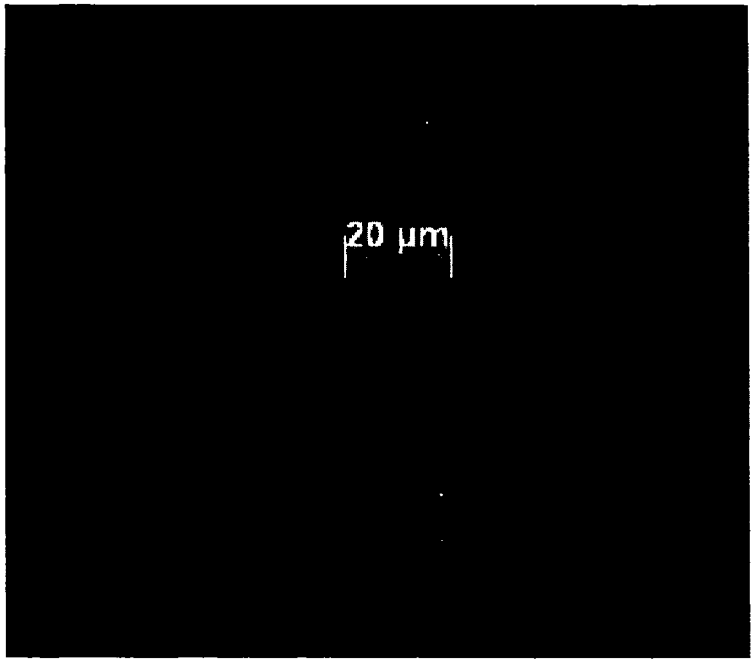

Figure 87.39: Starch of cf. *Hordeum*

Figure 87.40: Starch of cf. *Hordeum* (under polarize light)

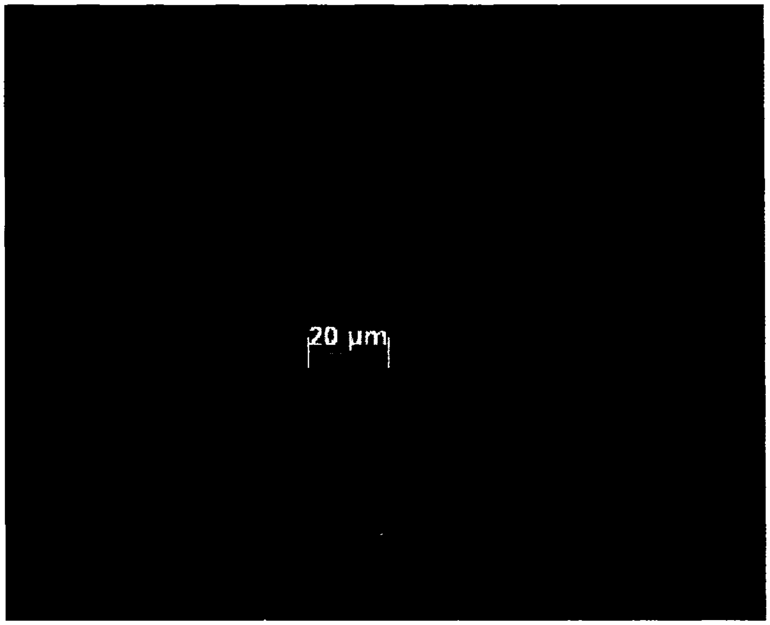

Figure 87.41: Starch of cf. *Hordeum* (measurement)

Figure 87.42: Bell Shaped Starch from pericarp of cf. *Solanum*

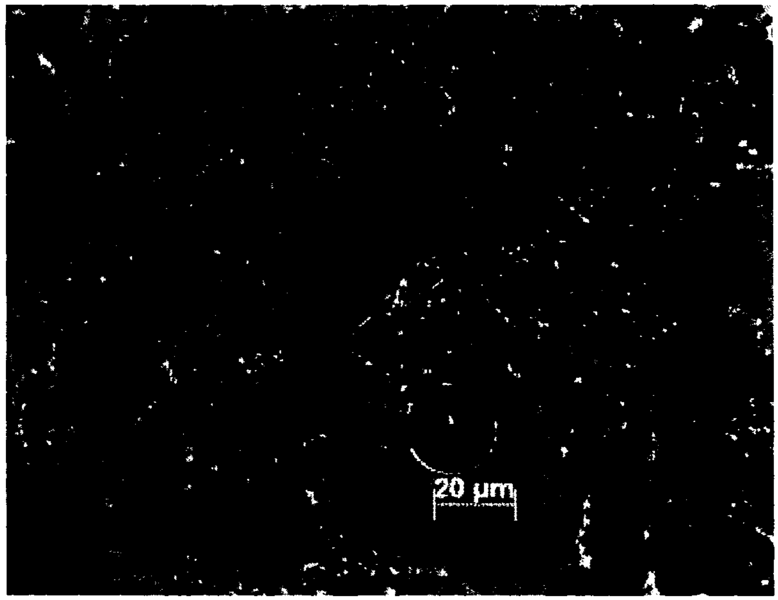

Figure 87.43: Starch of cf. *Hordeum*

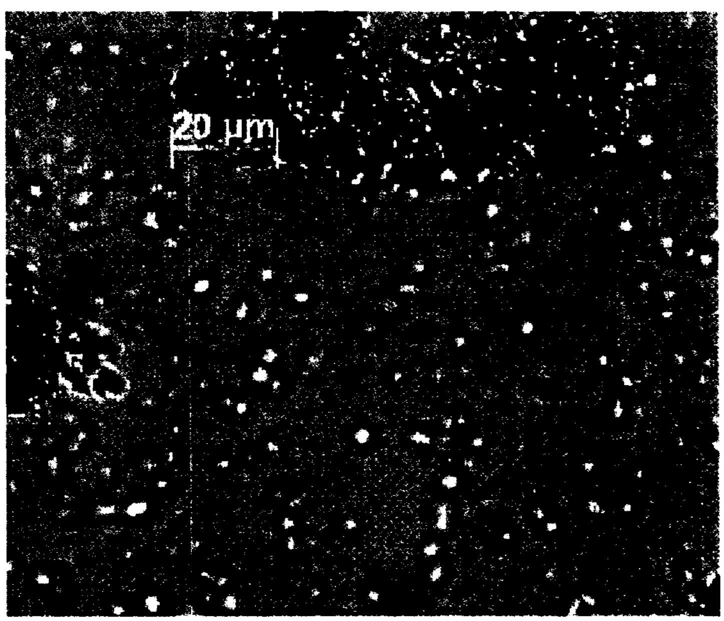

Figure 88.1: Unknown Starch

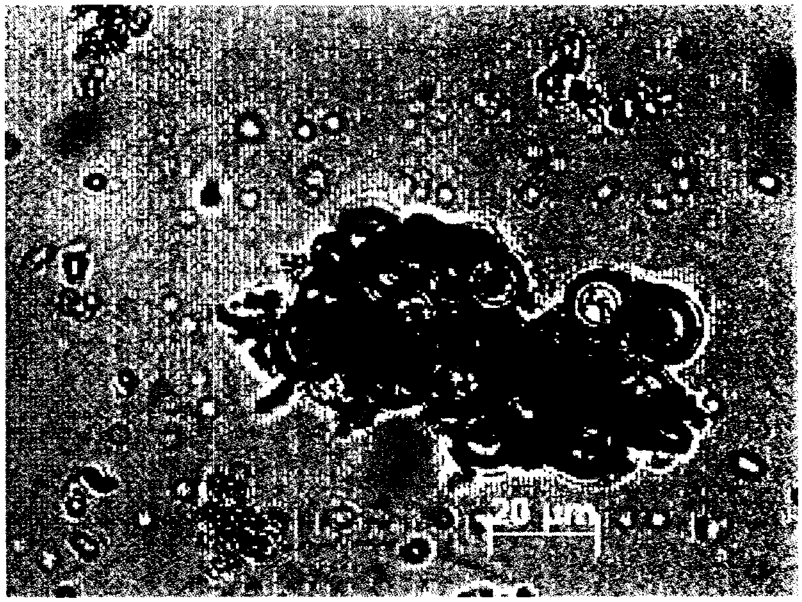

Figure 88.2: Unknown Starch

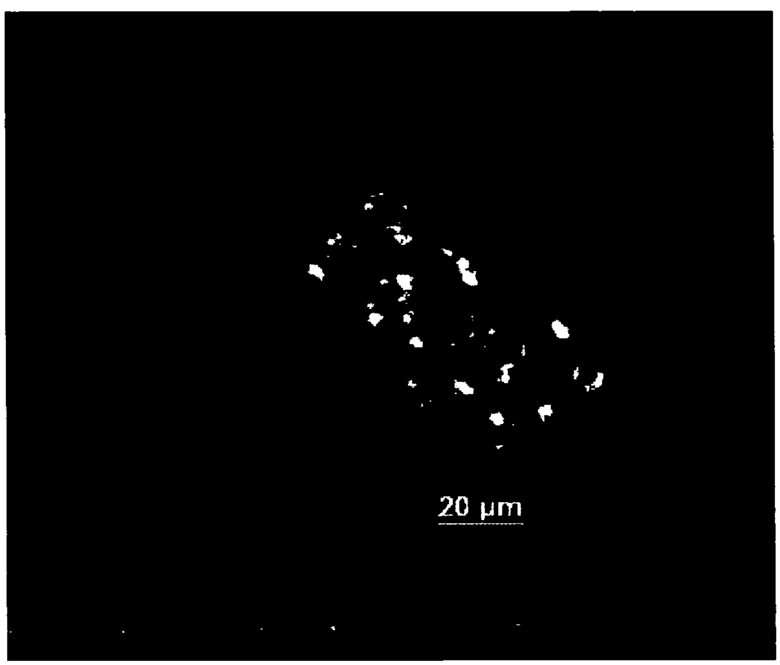

Figure 88.3: Unknown Starch (under polarize light)

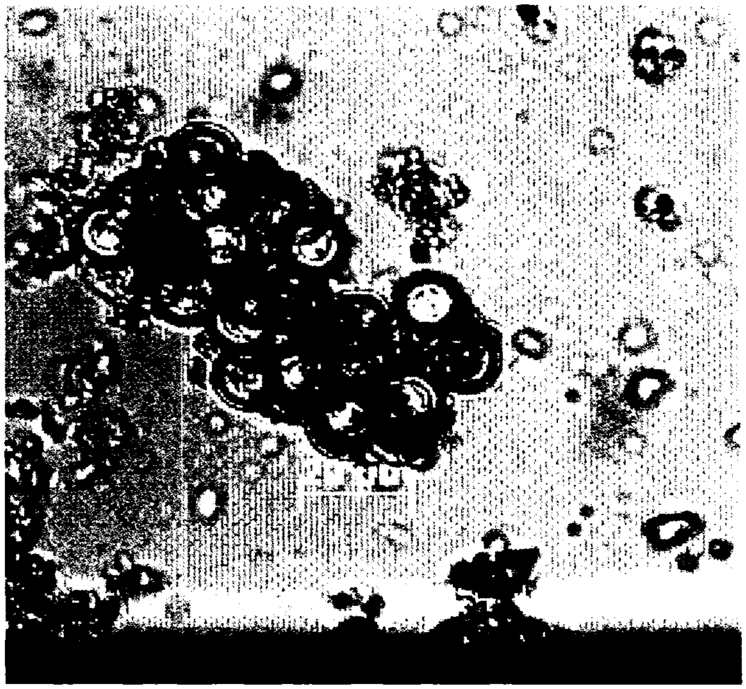

Figure 88.4: Unknown Starch

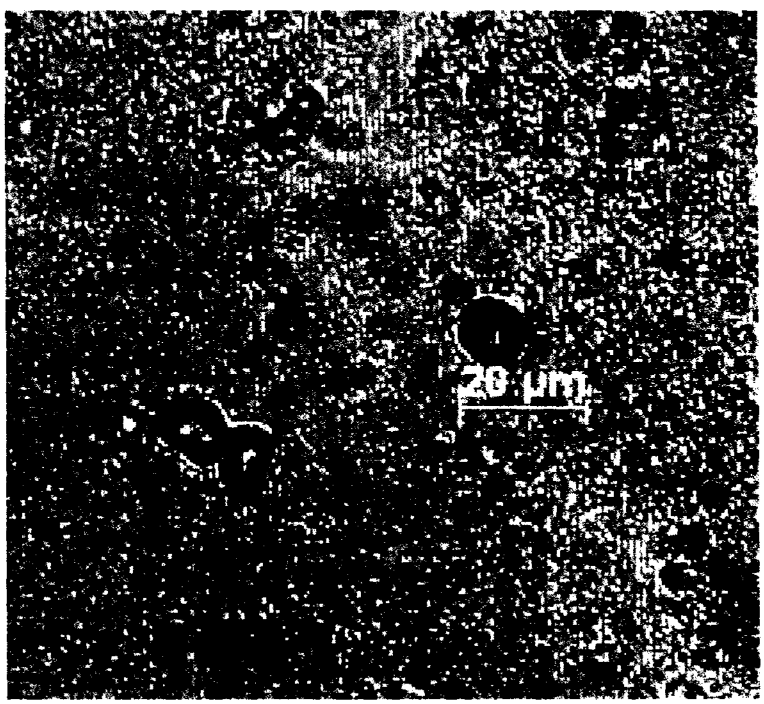

Figure 88.5: Unknown Starch

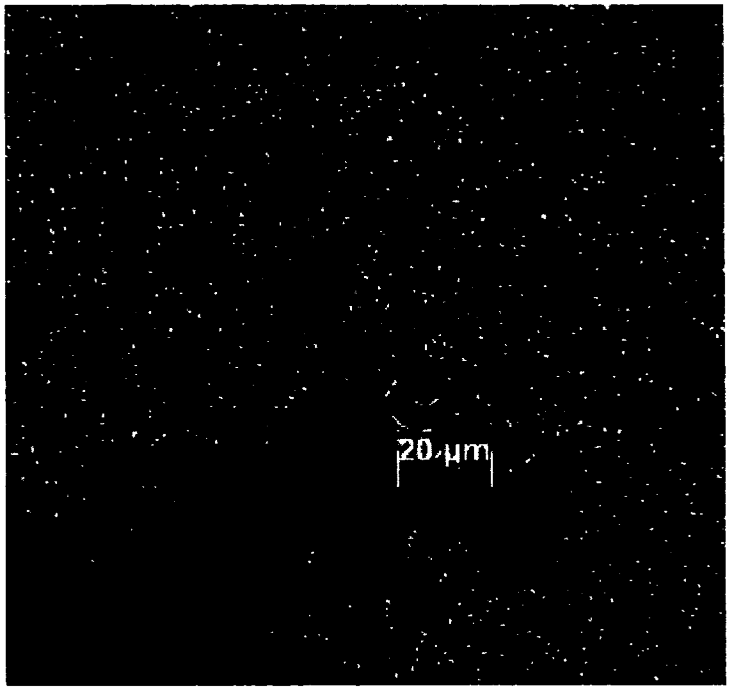

Figure 88.6: Unknown Starch

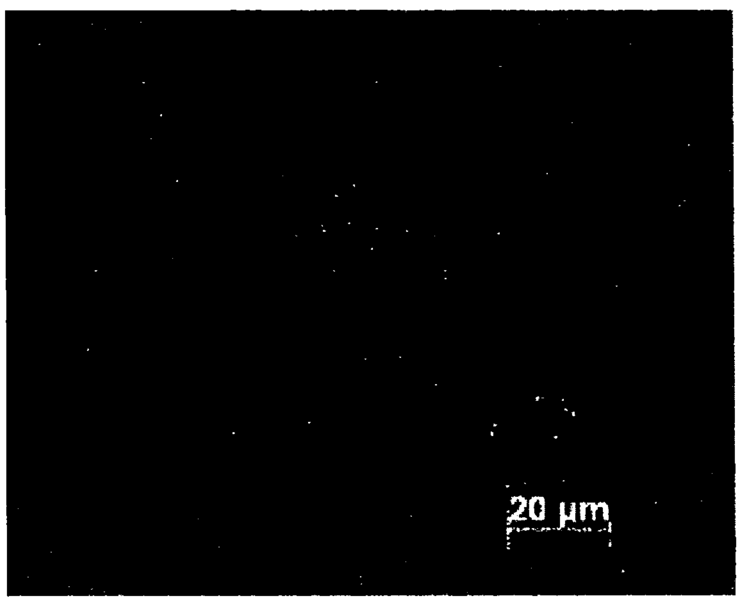

Figure 88.7: Spherical Starch of cf. *Solanum*

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